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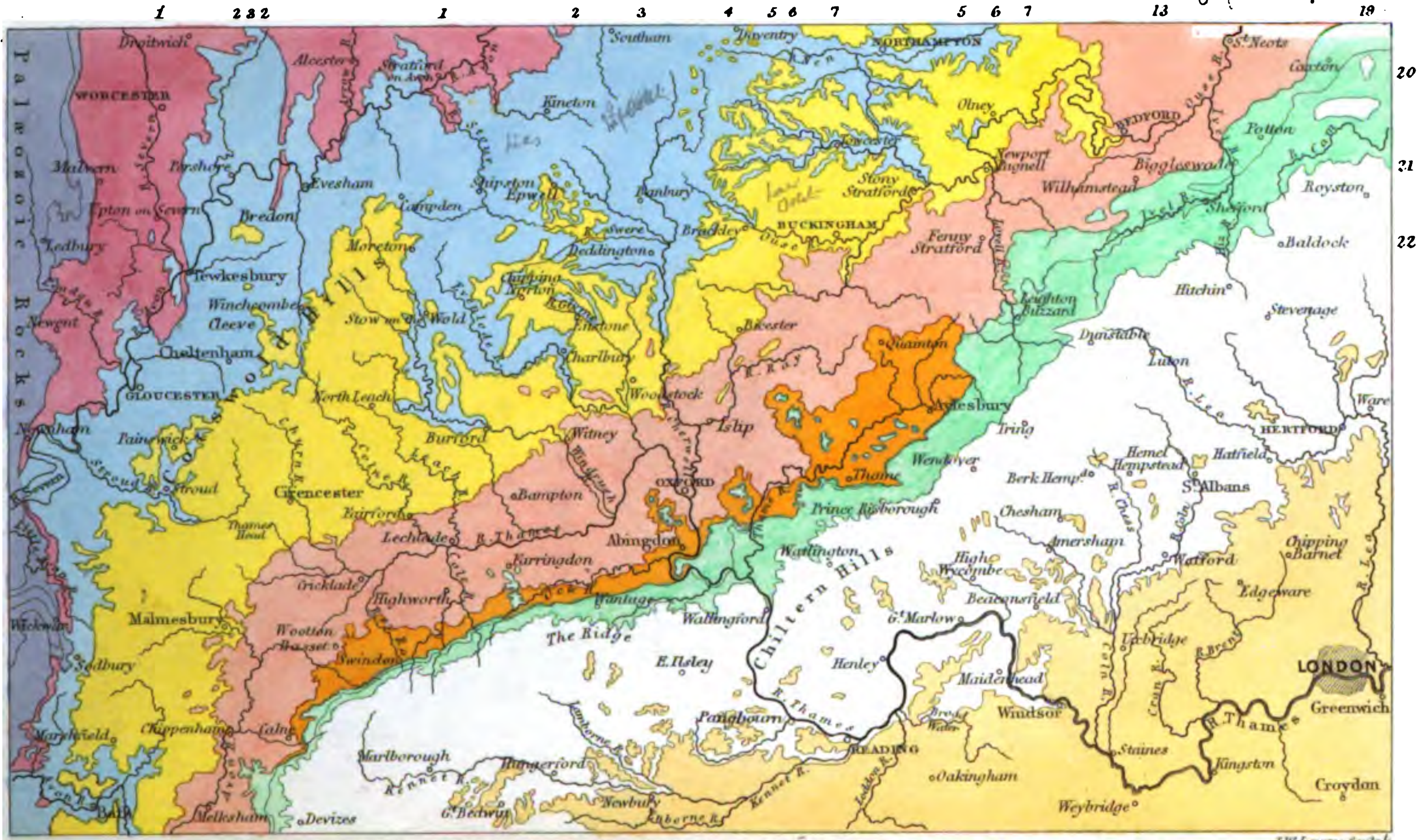
Plate I



The Numbers 1 to 22 refer to the Strata given in Sections Pl. III. & IV. where the same colours are employed.

J. W. Lowry, Sculpt.

GEOLOGY OF OXFORD

AND

THE VALLEY OF THE THAMES

BY

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Bristol and other Philosophical Institutions;
Tyneside and other Naturalists' Field Clubs.

FUNGAR INDICIS PARTIBUS.—*Plin. Epist.*

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TO

THE PRESIDENT AND FELLOWS OF MAGDALEN COLLEGE,

FIRM SUPPORTERS OF PHYSICAL SCIENCE IN OXFORD,

THIS WORK IS DEDICATED

BY ONE WHO IS NOT UNMINDFUL THAT TO THEIR

FRIENDLY RECOGNITION OF A LIFE'S DEVOTION TO GEOLOGY

HE OWES THE PRIVILEGE OF A PLACE

AMONG

THE HONORARY FELLOWS OF THE COLLEGE.

INTRODUCTORY NOTICE.

The history of that part of the earth's surface now occupied by the Valley of the Thames, as treated in these pages, embraces the whole period of geological time from the oldest rocks of Malvern to the latest prehistoric alluvium. The mind perceives and contemplates a long succession of lands and seas much different from those we now behold, the beginning and ending of many systems of associated life and varying physical agencies, all of which have had a traceable influence on the present aspect of this midland region of England.

After marking the main features of physical geography, and describing with the aid of maps and sections the systems of rocks in the order of time, the organic remains of each great group of strata are catalogued as fully as my own knowledge, combined with the valuable aids which are in each case thankfully acknowledged, has enabled me to accomplish the difficult task.

These catalogues are illustrated by numerous engravings.

The great series of reptilian bones, from the oolites, for which the Oxford Museum has long been celebrated, has been examined throughout, and the more remarkable genera have been made the subject of special description and many drawings to scale.

I could hardly have ventured on the great task of preparing these descriptions without the advantage of being able to consult at leisure the noble collection of Comparative Anatomy which some years since grew to celebrity under the care of Dr. Acland in Christ Church, and has since been greatly enriched in the

University Museum under the direction of the Linacre Professor, Dr. Rolleston. To him and to Mr. Charles Robertson, Demonstrator in Anatomy, it is a pleasure to be indebted for friendly help, always ready and always effective. I must add a further acknowledgment of the great assistance to myself and every student of physical science which is freely given in the magnificent library now attached to the Museum by the wise liberality of the Radcliffe Trustees.

I hope the care taken by my friends Mr. Lowry and Mr. Dewilde, in giving to my drawings the permanent form of expressive engraving, will prove as useful to the student as it has been gratifying to myself.

Though some years have been engaged in the preparation of this volume, I cannot regret the delay of publication, since it has enabled me to give a full account of that gigantic animal the Ceteosaurus, whose bones, dug out of the oolite in the interval, have been arranged in the University Museum, under my direction, by the steady hands of my assistant, Henry Caudel.

I know no country of such moderate extent in which so large a series of persistent marine life can be placed in sure co-ordination with physical conditions of land and sea through so long a range of continuous time. On this account it has been thought right to offer some reflections on the succession of the forms of life, which may help to a thoughtful consideration of modern 'theories of evolution,' and to examine with care the later effects of oceanic and atmospheric vicissitudes on rising and falling land, in connection with local changes of climate and occupation of the region by quadrupeds of many families older than the race of man.

CONTENTS.

CHAPTER I.—HISTORICAL NOTICES. PAGE

Origin of the Oxford Museums. Tradescant, Ashmole, Wilkins, Wren, Plot, Lhwyd, Smith, Kidd, Buckland, Conybeare, Strickland, Stacpoole, Whiteaves 1

CHAPTER II.—HILLS AND VALES.

The district in general. Ranges of hills and vales. Malvern Hills described, with sections and tables of principal elevations 9

CHAPTER III.—THE THAMES AND ITS TRIBUTARY RIVERS.

The names Tamesis and Isis considered. Thames-head. Peculiar freezing of the river. The Churn and Seven Wells. The Coln. The Leach. The Cole. The Windrush. The Dickler. The Evenlode. The Cherwell. The Ray. The Thames near Oxford. Ottmoor. The Ock. The Thame. The Kennet 23

CHAPTER IV.—PHYSICAL GEOGRAPHY.

Summits of drainage. Masses of submerged land. Rainfall. Winds. Temperature. Sites of population. Supply of water. Mineral springs. Fords. Forests. Ancient roads. Rollrich Stones. Devil's Coits 42

CHAPTER V.—THE OLDEST ROCKS OF ENGLAND.

The Malvern Rocks. Gneiss period. Crystalline structure. Various kinds of rock. Cambrian period. Fossils of the period. Figures of the fossils.. 58

CHAPTER VI.—THE SILURIAN PERIOD.

The series of strata. Classes of fossils imbedded. List of genera. Figures of fossils 69

PAGE

CHAPTER VII.—THE OLD RED AND CARBONIFEROUS PERIODS.

The Old Red Sandstone. Characters of the deposit. Notices of the fossils. *The Carboniferous Limestone.* Series of strata. Catalogue of genera of fossils. Figures of fossils. *The Coal measures* of Newent, Malvern, and Abberley. Figures and list of genera of fossil plants 77

CHAPTER VIII.—THE POIKILITIC PERIOD.

Relation of Permian to the new red deposits. *The Permian Series.* Diagrams in illustration of these deposits. Fossils of the series. *New Red* deposits and fossils. Figures of Dasyceps and Labyrinthodon. Retrospect .. 88

CHAPTER IX.—THE RHÆTIC PERIOD.

Character of the strata. Sections of Westbury Cliff. Wainlode Cliff. List of the fossils. Reference to Plate VII., containing figures of the fossils .. 101

CHAPTER X.—THE LIASSIC PERIODS.

Classification. *Lower lias.* Sections near Stratford-on-Avon. General view. *Marlstone.* Its range in England. Characteristic fossils. *Upper lias clay. Midford Sands.* Catalogue of liassic fossils. Zones of Ammonites. Ichthyosaurus. Reference to Plate VIII., containing figures of liassic fossils 108

CHAPTER XI.—THE BATH OOLITE PERIOD.

Classification of the strata. Ranges of the component parts. *Inferior oolite group. Fuller's-earth zone. Stonesfield beds. Great oolite. Bradford clay and Forest marble. Cornbrash.*

Fossils of the Inferior oolite. Reference to Plate IX., containing fossils of the Inferior oolite. Fossils of the Fuller's-earth rock.

Figures and lists of fossils of the Great oolite group, lower part. Stonesfield beds. Reference to Plate X., containing figures of Stonesfield fossils.

Figures and descriptions of reptilian remains found at Stonesfield, viz. Testudo, Teleosaurus, Megalosaurus, Rhamphorhynchus. Figures and descriptions of fossil mammalia found at Stonesfield.

Fossils of the Great oolite group, upper part. Reference to Plate XI., containing fossils of the group. Figures and descriptions of Ceteosaurus .. 137

CHAPTER XII.—THE OXFORD OOLITE PERIOD.

Composition of the strata. *Oxford clay and Kelloway rock. Calcareous grit. Coralline oolite.* Catalogue of fossils. Reference to Plate XII., representing fossils of the Oxford clay.

Figures and descriptions of Ichthyosauri, Plesiosauri, and Streptospondylus. Reference to Plates XIII. and XIV., representing fossils of the Coralline oolite and Calcareous grit 295

PAGE

CHAPTER XIII.—THE PORTLAND OOLITE PERIOD.

Composition of the strata. *Kimmeridge clay*, *Portland rocks*. Sections at Swindon, Bourton, and Great Hazeley. Fossils of the period. Reference to Plate XV., representing fossils of the Kimmeridge clay and Portland oolite.

Figures and descriptions of Ichthyosaurus, Pleiosaurus, Plesiosaurus, Steneosaurus, Dakosaurus, Ceteosaurus, Megalosaurus 324

CHAPTER XIV.—RETROSPECT OF THE OOLITIC SYSTEM.

Tripartite series of rocks. Composition of the oolite. Figures of the structure under the microscope. The iron ores. Distribution of life. Change of the forms of life in relation to time, illustrated by tables for Terebratulæ, Limæ, Trigoniæ, and Pholadomyæ. Discussion of the doctrine of 'modification by descent.' Comparison of the Stonesfield and Collyweston slate-beds 392

CHAPTER XV.—PURBECK BEDS AND IRON-SAND OF SHOTOVER.

Historical view. Ascent of Shotover Hill, with section in illustration. List of the organic remains. Other localities of the Purbeck beds and iron-sands, with fossils at several places. Reference to Plate XVI., containing section and figures of fossils 410

CHAPTER XVI.—THE CRETACEOUS PERIOD.

The component strata. *Lower greensand* and conglomerate traced. *Faringdon sponge-bed*. Culham clay-pit. Potton bone-bed. Catalogue of fossils of the Cretaceous system of the district round Oxford 422

CHAPTER XVII.—THE EOCENE PERIOD.

Waste of the chalk before the deposition of Eocene strata. Oyster-bed and sections near Reading. Newbury. 'Grey-weathers' or Sarsen stones. Strata under London. Mylne's map. Thanet sand. Woolwich bed in the lower part of the Vale of Thames 442

CHAPTER XVIII.—THE PLEISTOCENE PERIOD.

Early elevations of land followed by great rising and falling after eocene period. *Valley deposits and Hill deposits* contrasted. *High level gravel* on the Cotswolds, Chilterns, &c. Dr. Buckland's map and account of this gravel. Mr. Hull's account of the distribution. Action of ice. Mr. Lucy's observations. General view. *Low level gravel* in the course of the Thames and its feeders, at Yarnton, Oxford, Culham, Wittenham, &c. Composition of the gravel beds. Occurrence of land and fresh-water shells in the gravel

PAGE

at several places. The beds accumulated in broad waters. The descriptions continued below Reading, Brentford, Ilford, Grays-Thurrock. Land and fresh-water shells. Mammalia of the pleistocene zone below London and about Oxford. Flint implements found near Wittenham, Newbury, and other localities. Aborigines of Britain 456

CHAPTER XIX.—WASTE OF THE LAND.

Change of level of the sea considered. Great depression and re-elevation, and again great depression of the Tamisian area. Waste of the earth's surface by sea-action on the rising and falling land. Rains and rivers. Origin of valleys. Antiquity of gravel deposits. Changes of climate 481

CHAPTER XX.—ECONOMICAL APPLICATIONS.

Coal. Question of its existence and accessibility within the drainage of the Thames. *Iron ore* of Evenlode and Cherwell Valleys and Shotover Hill. *Brick, tiles, pottery. Ochre of Shotover. Fuller's-earth. Glass-sand. Potter's-clay. Water.* The condition of the Thames. Of Oxford wells. Hinksey water. Railway Lake water. Artesian wells recommended. Distant supply to replace the deficiencies of Thames 493

APPENDIX.

List of Genera of Oolitic Fossils 505

Additional Notices 511

ILLUSTRATIONS.

PLATE PAGE

I. Geological map of the country round Oxford, extending from the Malvern Hills to London, and embracing the feeders of the Thames as far south as the River Kennet .. .. .. *To face the Title.*

II. Geological map of the country immediately round Oxford, shewing the principal masses of low valley gravel, and the most remarkable of the scattered patches of higher northern drift 1

III. Longitudinal sections from the Downs of Wiltshire to Faringdon, and from Cirencester through Cheltenham to Tewkesbury 16

IV. Longitudinal sections from Cheltenham to Oxford, and from Broadway Hill to Shotover 32

V. Vertical section of mesozoic strata in Oxfordshire with characteristic organic remains 400

VI. Vertical section of mesozoic strata in Gloucestershire with characteristic organic remains 408

In the Illustrations Plates I. to VI. numbers are employed to mark the successive strata, the titles of the strata being given in Plate V. and Plate VI.

VII. Fossils of Rhætic and Lowest lias .. .. .. *Referred to at page* 107

VIII. Fossils of the Lias .. .. " 136

IX. Fossils of the Inferior oolite .. .. .. " 165

X. Fossils of the Stonesfield beds .. .. .. " 181

XI. Fossils of the Great oolite, Forest marble, and Cornbrash " 244

XII. Fossils of the Oxford clay .. .. " 306

XIII. Fossils of the Coralline oolite and Calcareous grit " 323

XIV. Fossils of the Coralline oolite and Calcareous grit " 323

XV. Fossils of the Kimmeridge clay and Portland oolite " 333

XVI. Fossils of the iron-sand and sections of Shotover .. " 421

XVII. Fossils of the sponge-bed of Faringdon .. .. " 441

DIAGRAM		PAGE
I.	Section of Strata on the Cherwell, by W. Smith	4
II.	Sketch of Strata near Banbury, by Rev. W. Conybeare	6
III.	Section across the country from the Malvern Hills to the River Kennet	11
IV.	Section of the Malvern Hills	12
V.	Section across the Vale of Severn	14
VI.	Section across the Cotswold escarpment	16
VII.	Section across the upper part of the Vale of Thames	18
VIII.	Section through Oxford from Wytham Hill to Shotover Hill ..	18
IX.	Section across the Cretaceous strata	19
X.	'The very Head of Isis.'—Leland	26
XI.	The Seven Wells	29
XII.	Land submerged 250 feet	43
XIII.	Land submerged 500 feet	44
XIV.	Land submerged 1000 feet	45
XV.	Rollrich Stones	56
XVI.	Crystalloid Stones of Malvern	63
XVII.	Cambrian Fossils of Malvern	68
XVIII.	Silurian Fossils of Malvern	76
XIX.	Fishes of the Old Red Sandstone of the Malvern district	79
XX.	Fishes of the Carboniferous Limestone of Bristol	84
XXI.	Mountain Limestone Fossils	84
XXII.	Coal Measure Plants, Forest of Dean	86
XXIII.	Section of Sedimentary Shore Deposits	92
XXIV.	Section of Deposits against a fault	93
XXV.	Crania of Labyrinthodont reptiles	98
XXVI.	Paddles of Ichthyosaurus	135
XXVII.	Section of Strata at Worton	145
XXVIII.	Stonesfield Ferns	169
XXIX.	Bucklandia squamosa	170
XXX.	Stonesfield Cycadaceæ	171
XXXI.	Stonesfield Coniferæ	172
XXXII.	Stonesfield Fruits	173
XXXIII.	Buprestidium—Stonesfield	174

DIAGRAM PAGE
XXXIV. Curculionidium—Stonesfield 174
XXXV. Hemerobioides giganteus 174
XXXVI. Libellula Westwoodii 174
XXXVII. Teeth of Placoid Fishes 177
XXXVIII. Stonesfield Fishes—Spines 178
XXXIX. Pycnodont Fishes of Stonesfield 179
XL. Fishes of Stonesfield 180
XLI. Scales and Scutes—Stonesfield 182
XLII. Teeth of Teleosaurians 185
XLIII. Head of Teleosaurus brevidens 186
XLIV. Lower Jaw of Teleosaurus brevidens 187
XLV. Teleosaurus—End of Jaws 188
XLVI. Occipital Views of Teleosaurus, Gavial, and Steneosaurus 189
XLVII. Dorsal Vertebræ of Teleosaurus 190
XLVIII. Sacral Vertebra of Teleosaurus 190
XLIX. Sacral Vertebra of Teleosaurus 191
L. Caudal Vertebræ of Teleosaurus 191
LI. Ischia of Teleosaurus 192
LII. Pubis of Teleosaurus 193
LIII. Femora of Teleosaurus and Steneosaurus 193
LIV. Teleosaurus subulidens—Jaw 194
LV. Lower Jaw of Teleosaurus subulidens 195
LVI. Tooth of Megalosaurus 198
LVII. Head of Megalosaurus 199
LVIII. Cervical Vertebræ of Teleosaurus and Megalosaurus 200
LIX. Sacral and Dorsal Vertebræ of Megalosaurus 202
LX. Anterior Dorsal of Megalosaurus 203
LXI. Cross Sections of Sacral Vertebræ 206
LXII. Caudal Vertebra of Megalosaurus 207
LXIII. Shoulder-Girdle of Megalosaurus 208
LXIV. Restored Hind-Leg of Megalosaurus 210
LXV. Ischium of Megalosaurus 211
LXVI. Pubis of Megalosaurus 212
LXVII. Small Ilium of Megalosaurus 212

DIAGRAM		PAGE
LXVIII.	Metatarsal Bones of Megalosaurus, Crocodile, and Iguanodon	215
LXIX.	Metatarsal and Ungual of Megalosaurus	217
LXX.	Restoration of Rhamphorhynchus	221
LXXI.	Mandible of Rhamphorhynchus	221
LXXII.	Vertebræ of Rhamphorhynchus	222
LXXIII.	Wing-Finger, Shoulder-Girdle, &c. of Rhamphorhynchus	223
LXXIV.	First Phalanx of Wing-Finger of Rhamphorhynchus	224
LXXV.	Lacunæ in bones of Lepidotus, Alligator, and Rhamphorhynchus	225
LXXVI.	Bones of Hind-Leg of Rhamphorhynchus	226
LXXVII.	Amphitherium Prevostii	233
LXXVIII.	Another Specimen	233
LXXIX.	Another Specimen	234
LXXX.	Amphitherium Broderipii	234
LXXXI.	Phascolotherium Bucklandi	235
LXXXII.	Portion of Jaw of Phascolotherium Bucklandi	236
LXXXIII.	Stereognathus ooliticus	236
LXXXIV.	Plan of the distribution of Bones of Ceteosaurus in the oolite	250
LXXXV.	Tooth of Ceteosaurus	253
LXXXVI.	Dorsal Vertebra of Ceteosaurus	254
LXXXVII.	Posterior Zygapophysis of Ceteosaurus	256
LXXXVIII.	Dorsal Vertebra of Ceteosaurus	257
LXXXIX.	Anterior Caudal of Ceteosaurus	259
XC.	Pre-medial Caudal (three views)	260
XCI.	Post-medial Caudal (three views)	261
XCII.	Anterior Caudal (in front)	262
XCIII.	Anterior Caudal (behind)	262
XCIV.	Anterior Caudal (lateral)	263
XCV.	Middle Caudal (three views)	265
XCVI.	Posterior Caudal (three views)	266
XCVII.	Ribs of Ceteosaurus	267
XCVIII.	Sternum and Coracoid	268
XCIX.	Scapulæ of Ceteosaurus (two views)	270
C.	Humerus of Ceteosaurus (two views)	272

DIAGRAM		PAGE
CI.	Humerus of Ceteosaurus (young)	273
CII.	Humerus of Ceteosaurus	274
CIII.	Ulna of Ceteosaurus (three views)	275
CIV.	Pelvic Girdle of Ceteosaurus	277
CV.	Ilium of Ceteosaurus (external)	278
CVI.	Ilium of Ceteosaurus (edgeways)	279
CVII.	Ilium of Ceteosaurus (internal)	279
CVIII.	Femora and Fibula of Ceteosaurus	281
CIX.	Tibia of Ceteosaurus (four views)	282
CX.	Tibia of young Ceteosaurus (two views)	283
CXI.	Foot-Bones of Ceteosaurus, Megalosaurus, and Crocodile	286
CXII.	Foot-Bones of Ceteosaurus (three views)	288
CXIII.	Cervical Vertebræ of Plesiosaurus Oxoniensis	308
CXIV.	Dorsal Vertebræ of Plesiosaurus Oxoniensis (four views)	309
CXV.	Caudal Vertebræ of Plesiosaurus Oxoniensis	310
CXVI.	Pelvic Girdle of Plesiosaurus Oxoniensis	310
CXVII.	Paddle of Plesiosaurus Oxoniensis	312
CXVIII.	Cervical Vertebræ of Plesiosaurus plicatus (sideways)	313
CXIX.	Cervical Vertebræ of Plesiosaurus plicatus (three views)	313
CXX.	Paddle of Plesiosaurus eurymerus	315
CXXI.	Paddle of Pleiosaurus grandis	317
CXXII.	Lower Jaw of Pleiosaurus grandis	318
CXXIII.	Anterior Extremity of Upper Jaw of Megalosaurus	320
CXXIV.	Anterior Dorsal of Streptospondylus Cuvieri	321
CXXV.	Wood from Kimmeridge clay	329
CXXVI.	Anterior Cervical Vertebra of Ichthyosaurus trigonus (three views)	335
CXXVII.	Posterior Cervical Vertebra of Ichthyosaurus trigonus (three views)	336
CXXVIII.	Anterior Caudal of Ichthyosaurus trigonus (three views)	337
CXXIX.	Cervical Vertebra of Ichthyosaurus thyreospondylus (three views)	337
CXXX.	Anterior Dorsal of Ichthyosaurus thyreospondylus (four views)	338
CXXXI.	Caudal Vertebra of Ichthyosaurus thyreospondylus (two views)	338
CXXXII.	Tooth of Ichthyosaurus or Polyptychodon	340

DIAGRAM		PAGE
CXXXIII.	Coracoids and Paddle-Bones of Ichthyosaurus	340
CXXXIV.	Upper Jaw of Pleiosaurus brachydeirus	342
CXXXV.	Lower Jaw of Pleiosaurus brachydeirus	343
CXXXVI.	Teeth of Pleiosaurus brachydeirus	344
CXXXVII.	Cervical Vertebra of Pleiosaurus brachydeirus (three views)	345
CXXXVIII.	Posterior Cervical (two views)	345
CXXXIX.	Dorsal Vertebra of Pleiosaurus brachydeirus (three views)	346
CXL.	Lumbar Vertebra of Pleiosaurus brachydeirus (two views)	347
CXLI.	Caudal Vertebra of Pleiosaurus brachydeirus (three views)	347
CXLII.	Coracoids of Pleiosaurus	348
CXLIII.	Pelvic Bones of Pleiosaurus	349
CXLIV.	Pelvic Bones of Pleiosaurus	350
CXLV.	Ischium of Pleiosaurus	351
CXLVI.	Paddle Bones of Pleiosaurus brachydeirus	352
CXLVII.	Phalangal Bones of Pleiosaurus brachydeirus	353
CXLVIII.	Anterior Cervical of Pleiosaurus macromerus (two views)	354
CXLIX.	Posterior Cervical of Pleiosaurus macromerus (two views)	355
CL.	Dorsal Vertebra of Pleiosaurus macromerus (two views)	356
CLI.	Caudal Vertebra of Pleiosaurus macromerus (two views)	356
CLII.	Cervical Vertebra of Pleiosaurus gamma (four views)	358
CLIII.	Dorsal Vertebra of Pleiosaurus gamma (three views)	359
CLIV.	Lumbar Vertebra of Pleiosaurus gamma (two views)	359
CLV.	Caudal Vertebra of Pleiosaurus gamma (two views)	360
CLVI.	Cervical Vertebra of Pleiosaurus nitidus (three views)	360
CLVII.	Dorsal Vertebra of Pleiosaurus nitidus	361
CLVIII.	Caudal Vertebra of Pleiosaurus nitidus (two views)	361
CLIX.	Femur of Pleiosaurus macromerus	362
CLX.	Humerus of Pleiosaurus brachydeirus	363
CLXI.	Femur of Pleiosaurus grandis	363
CLXII.	Humerus of Pleiosaurus trochanterius	364
CLXIII.	Humerus of Pleiosaurus trochanterius	365
CLXIV.	Femur of Pleiosaurus æqualis	365
CLXV.	Femur of Pleiosaurus simplex	366

DIAGRAM PAGE

CLXVI. Phalangal Bone of Pleiosaurus macromerus (two views) .. 367
CLXVII. Rib of Pleiosaurus 367
CLXVIII. Cervical Vertebra of Plesiosaurus brachyspondylus (two views) 368
CLXIX. Dorsal Vertebra of Plesiosaurus brachyspondylus (two views) 369
CLXX. Dorsal Vertebra of Plesiosaurus brachyspondylus (sideways) 370
CLXXI. Cervical Vertebra of Plesiosaurus validus (two views) .. 371
CLXXII. Caudal Vertebra of Plesiosaurus validus (four views) .. 372
CLXXIII. Cervical Vertebra of Plesiosaurus plicatus (three views) .. 373
CLXXIV. Cervical Vertebra of Plesiosaurus (three views) 374
CLXXV. Cervical Vertebra of Plesiosaurus carinatus (two views) .. 375
CLXXVI. Caudal of Plesiosaurus hexagonalis 375
CLXXVII. Ischial Bones of Plesiosaurus 377
CLXXVIII. Ischial Bones of Plesiosaurus 377
CLXXIX. Coracoids of Plesiosaurus 378
CLXXX. Ischia of Plesiosaurus 379
CLXXXI. Pair of Coracoids 379
CLXXXII. Head of Steneosaurus palpebrosus (seen from below and from above) 381
CLXXXIII. Lower Jaw of Steneosaurus palpebrosus (two views) 381
CLXXXIV. Shoulder-Girdle of Steneosaurus palpebrosus 382
CLXXXV. Dorsal Vertebræ of Steneosaurus palpebrosus (four views) .. 382
CLXXXVI. Bones of Steneosaurus palpebrosus 383
CLXXXVII. Ischium of Steneosaurus palpebrosus 383
CLXXXVIII. Head of Steneosaurus gracilis (two views) 385
CLXXXIX. Head and Bones of Steneosaurus gracilis 387
CXC. Tooth of Steneosaurus longirostris 388
CXCI. Tooth of Dakosaurus (two views) 389
CXCII. Reptilian Tooth (two views) 389
CXCIII. Magnified Sections of grains of Oolite 395
CXCIV. Magnified View of a Discoid Foraminifer constituting a grain of Oolite 396
CXCV. Grains of Bath Oolite magnified 397
CXCVI. Section of Strata at Culham 427
CXCVII. Ammonites Sussexiensis 440

DIAGRAM		PAGE
CXCVIII.	Ammonites varians	440
CXCIX.	Turrilites tuberculatus	440
CC.	Section of Eocene beds in the Vale of Thames at London	443
CCI.	Section of Eocene beds in the Vale of Kennet	444
CCII.	Section across the Vale of Thames at Gray's-Thurrock	471
CCIII.	Flint Implements of early type (Wittenham and Hounslow)	475
CCIV.	Flint Implements of later type (Wittenham)	476
CCV.	Flint Implement ground over all the surface (Wittenham)	477
CCVI.	Greenstone Implement from Wittenham	478
CCVII.	Stone Implement from Shotover Hill	478

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Lindley	Fossil Flora, 8vo. 1831.
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Orbigny, D'	Palæontologie française, 8vo. 1848.
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Owen	On Fossil Reptiles, in Pal. Soc. Mem.; Reports of Brit. Assoc. &c.; Fossil Mammalia, &c. 1839.
Parkinson	Organic Remains, 4to. 1811.
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Plot	Nat. Hist. of Oxfordshire, fol. 1677.
Portlock	Geol. Rep. on Londonderry, 8vo. 1843.
Prestwich	Memoirs on Eocene and Pleistocene Geology, in Geol. Soc. Journ.
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Reinecke	Maris Protogæi, &c., 8vo. 1818.
Reuss	Geog. Verhält., 1844.
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Sanders	Distribution of Fossils in Lias.
Schlotheim	Petrefactenkünde, 4to. 1804.

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Woodward, H., & Lowry	Fossil Crustacea, 1865.
Woodward, S.	Geol. of Norfolk, 8vo. 1833.
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Wright	British Echinodermata, in Pal. Soc. Mem.; Ammonites, in Proc. Cotswold Club, &c. 1856.
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Zieten	Die Versteinerungen Würtemberg's, 4to. 1830.

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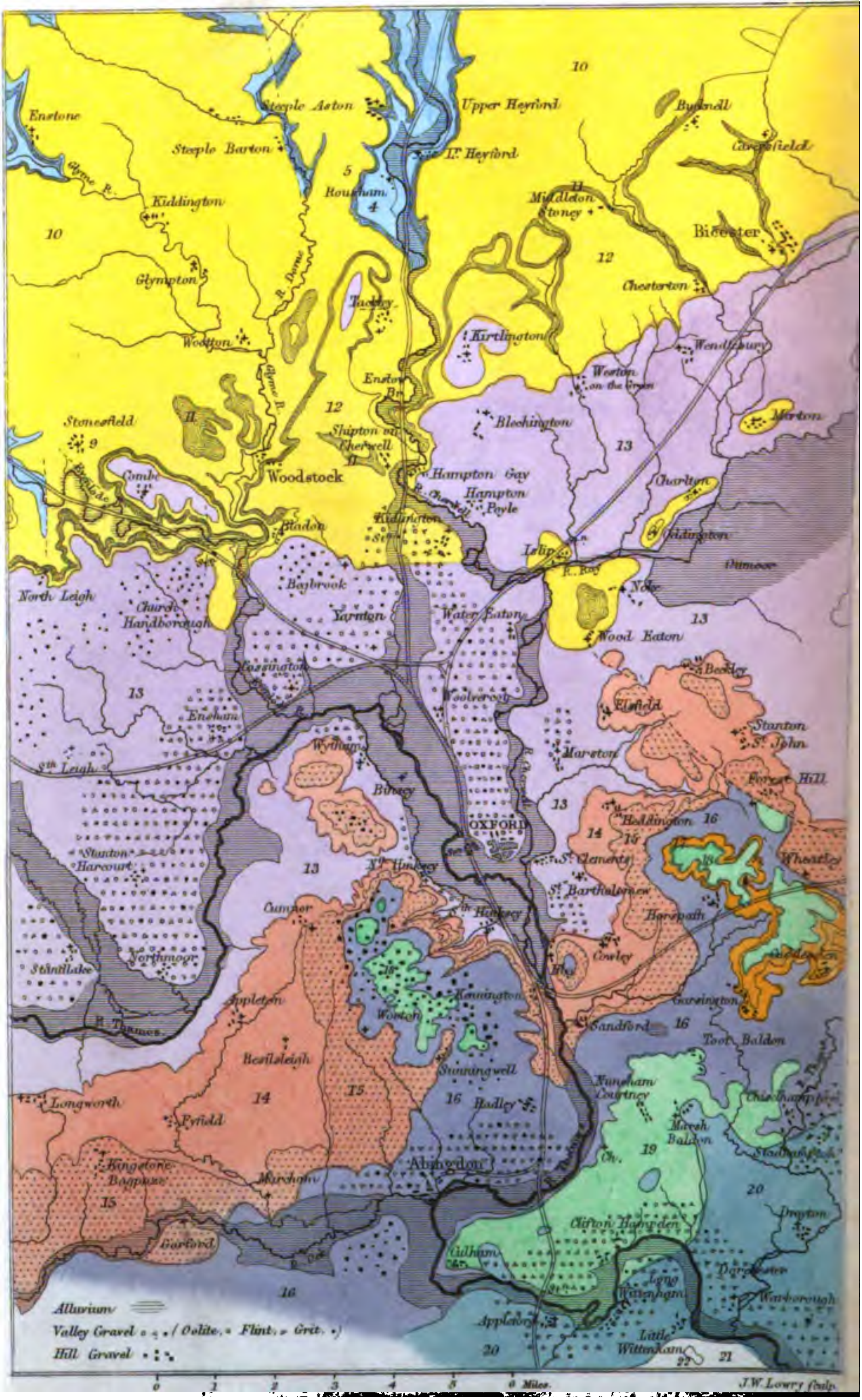
Plate I


Enstone
Glyme R.
Steeple Aston
Steeple Barton
Upper Heyford
Lr. Heyford
Bucknell
Caversfield
Kiddington
Rousham
Middleton Stoney
Bicester
Glympton
R. Dorn
Tackley
Chesterton
Kirtlington
Wootton
Wendlebury
Glyme R.
Enslow Br.
Weston on the Green
Stonesfield
Shipton on Cherwell
Blechington
Merton
Combe
Woodstock
Hampton Gay
Hampton Poyle
Charlton
Evenlode
R. Cherwell
Bladon
Kidlington
Islip
Oddington
Otmoor
R. Ray
Begbrook
Noke
North Leigh
Church Handborough
Yarnton
Water Eaton
Wood Eaton
Cassington
Beckley
Elsfield
Eynsham
Wolvercot
Stanton St. John
Wytham
Marston
Sth. Leigh
Forest Hill
Binsey
Headington
OXFORD
Stanton Harcourt
Nth. Hinksey
St. Clements
Wheatley
St. Bartholomew
Cumnor
Sth. Hinksey
Horspath
Cowley
Northmoor
Standlake
Iffley
Kennington
Appleton
Wootton
Garsington
Sandford
R. Thames
Toot Baldon
Besilsleigh
Sunningwell
Nuneham Courtney
Chiselhampton
Longworth
Radley
Fyfield
Marsh Baldon
Kingstone Bagpuze
Abingdon
Stadhampton
Marcham
Clifton Hampden
Drayton
Garford
R. Ock
Culham
Dorchester
Long Wittenham
Warborough
Appleford
Little Wittenham
R. Thames
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18
19
20
20
21
22
Alluvium
Valley Gravel (Oolite, Flint, Grit)
Hill Gravel
0 1 2 3 4 5 6 Miles
J.W. Lowry fculp.

CHAPTER I.

HISTORICAL NOTICES.

THE Museums of the University of Oxford contain the oldest Public Collection ever formed in the British Isles for the illustration of Natural History, Antiquities, and Archæology.

This Collection was first gathered, as so many others have been, round the nucleus of a garden.

John Tradescant, a Dutchman, came to England about the end of the sixteenth century, and, like our famous Gerarde, who was chief gardener to Lord Burleigh, 'a great lover of plants,' he entered the service of Lord-Treasurer Salisbury and Lord Wootton, and afterwards became gardener to King Charles I. Travelling in various parts of Europe, including Russia, and penetrating into Barbary, he brought home plants and other 'rariora.' The plants furnished his garden at West Lambeth; the other curiosities grew, by additions, to a museum known as Tradescant's Ark[a]. A catalogue of this collection, under the title of Museum Tradescantianum, contains a remarkable list of many natural objects:—animals, plants, minerals, besides a variety of warlike instruments, habits, utensils, coins, and medals. Appended to it is a catalogue of the plants cultivated in his garden at Lambeth[b]. He was designed for the appointment of gardener to the 'Physic Garden' founded by Lord Danby at Oxford in 1622–1633, at a yearly stipend of about £50; but died in 1638, without actually entering on his office.

The son of Tradescant, also named John, inherited his father's collections and his botanical tastes. To him we owe the gardenflower Tradescantia, which he brought from Virginia. He died in 1662, having presented his collections, by deed of gift in 1659, to Elias Ashmole, who, among his various studies, had included Botany, and had made the acquaintance of

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[a] Evelyn, in his Diary, notices, as one of the chief rarities of the collection, 'a feather from the Phœnix' wing' (vol. i. p. 322).

[b] 1656. 12mo.

'Both gardeners to the Rose and Lily Queen[c].'

Elias Ashmole, born at Lichfield in 1617, led a varied and busy life, in which only one strong line can be traced, marking his knowledge of and attachment to heraldry. The additions which he made to the old collection consisted mainly of coins, medals, and metallic works of art, besides valuable manuscripts and books of heraldry and astrology, which once belonged to Lilly.

Ashmole was much in Oxford during the disastrous civil wars (acting as a gentleman in the Ordnance, and officiating as a clergyman during the siege), and afterwards co-operating with the philosophical party of Oxonians, with Wilkins at their head, who heralded the Royal Society. In 1669, Ashmole was complimented with a degree, and some years after announced his intention of presenting his collections to the University. In 1679, the edifice was begun which for almost two centuries was destined to hold this historical collection, and was finished in 1683. The design has been attributed to Sir Christopher Wren; but there is no authority for this. On a contemporary engraving, representing the Museum, by M. Burghers, Mr. T. Wood is named as the architect.

From the day when these unique collections came into the hands of the University, a strong tendency was manifested to make them contribute to the 'new philosophy,' as it was termed, which had been inaugurated by the Royal Society. Plot, the first keeper of the Museum, appointed in 1683, the year of the completion of the building, gave, as is well known, diligent, if not successful, attention to the 'formed stones' and other natural curiosities of Oxfordshire. His Natural History of this County, a model for many subsequent works, was not, indeed, confined to the subjects truly embraced by the title; for it contains good information on Roman and other antiquities, and something more than a smattering of what is now called Physics.

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[c] So the Tradescants are styled on their monument in Lambeth Churchyard.

Edward Lhwyd, who in 1690 succeeded Plot, has left us a special work on organic remains which had been collected in the Ashmolean Museum. In the Lithophylacium Britannicum we have an account of fossils of a remarkable character which he had found or had received from his friends, and arranged in cabinets in the Museum. The number of specimens referred to is 1766, and the descriptions are aided by twenty-five plates of figures, besides some woodcuts. In this remarkable volume, the localities of fossils which most frequently meet the eye are found in the vicinity of Oxford; but Lhwyd extended his researches to South Wales, Somerset, Gloucestershire, Northamptonshire, and most parts of England, and by correspondence was made acquainted with discoveries in Germany.

About half the localities mentioned by Lhwyd are found within a distance of twenty miles from Oxford, and among these the most prolific quarries and pits are still the favourite haunts of the collector—Stonesfield, Bullingdon, Cowley, Garsington, Wheatley, Cumnor, Faringdon, Islip, Marcham, Thame, continually occur. Shotover, indeed, is but rarely mentioned; perhaps the clay-pits on the slope of the hill were not then opened, or not much worked in that age of stone-building. It is indeed to the prevalent habit of employing the 'freestone' for building through all the oolitic country that we owe the greater part of the fossils of this district. It is perhaps remarkable that no 'large bones' are noticed from Stonesfield, which was already famous for its 'glossopetræ' and other remains of fishes, and yielded continually abundance of 'slat' stone for the roofs of colleges and houses in Oxford.

The district which it is the purpose of the following pages to describe in its geological relations, has been not merely traversed but diligently examined by many eminent persons following in the steps of the early explorers who have been named; and many detached essays have contributed to illustrate the structure of the country and its fossil contents. But there has been no complete or connected view of either.

Toward the close of the last century, William Smith, a native of Churchill, in Oxfordshire[d], following the profession of a civil engineer, had acquired a perfect knowledge of the stratification of England, and had constructed geological maps of the kingdom at large, and of several counties in particular. He did not however fully publish these results of his labours till 1814, when the great Map of the Strata of England and Wales appeared, followed at intervals by maps of twenty-one English counties, including Oxfordshire and Gloucestershire.

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[d] Memoirs of William Smith, LL.D. His birth-year was 1769—death in 1839.

One of his early observations in the valley of the Cherwell, between Rowsham and Steeple Aston, was illustrated by the sketch section of the strata which is presented below.

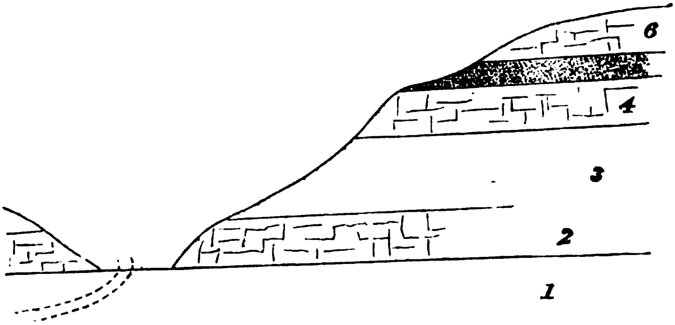

Diagram I. 1. Sandy clay. 2. Rock, 20 feet. 3. Wet clay. (Spring of water here.) 4. Ovenstone or soft sandstone. 5. White sand, 6 feet. 6. White stone. The Road to Hopcroft's Holt is dotted.

Dr. Kidd was Professor of Chemistry, and conducted his much-attached students to other branches of natural science in Oxford during the first quarter of this century. In 1815 he published a 'Geological Essay,' containing several observations of value in relation to the country round Oxford, and specially clearing up much of the confusion which prevailed respecting the gravel deposits at different levels in the Thames valley and on the bordering hills[e].

We next come to the great name of Buckland[f], born at Axminster, amidst rocks full of fossils like many which were common about Oxford. In my boyhood many amusing stories attested the untiring energy and independence of thought of this 'master workman' in geology, who frequently rode by the home of the Rev. Benjamin Richardson, of Farley Castle, not unfrequently loaded with and exulting in the spoils of his hammer, and always inquired what 'Strata Smith' was doing. We have from his hand the admirable work entitled Reliquiæ Diluvianæ, which gives much information in regard to our local geology, and one of the most precious parts of our Collection of Fossils. A special memoir on the Megalosaurus of Stonesfield may be referred to as one of the many successful efforts of a mind at once sagacious and speculative, bold and cautious, beyond the ordinary standard.

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[e] Dr. Kidd also published, in 1809, a rather considerable volume on mineralogy.

[f] Obituary notice in Proceedings of Royal Society, 1856: Born, 1784; Died, 1856.

It is perhaps remarkable that no preparation was made by this acknowledged leader of Geology for a descriptive work such as is now attempted, the more so as a skilful hand and sympathizing mind were always ready to share his labour[g].

The name of William Conybeare will always be associated with that of Buckland in the history of Geology at Oxford. Nearly contemporaries, kindred spirits, and faithful friends, they traversed together many parts of the Oxfordshire district, and some considerable results of this pleasant work appear in the Geology of England and Wales[h], 1829. The second volume of this work, destined to include Silurian and Cambrian discoveries, expected in vain from Dr. Conybeare, no one has dared to add; nor, even after the admirable publications of Murchison[i] and Sedgwick[k], can the task be thought a light one. My note-book of June 1831 contains a sketch by Dr. Conybeare of the strata in the country north of Oxford, of which a copy is given on p. 6. We were examining, in the Bodleian, Nichols' History and Antiquities of Leicestershire, with reference to the Marlstone, a division of the Lias to which I had called particular attention[l]; and the sketch referred to shows in what manner he made the application of those observations to the district round Banbury. My last interview with this truly superior man was on the ruined cliffs of Culverhole, in 1840.

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[g] Mrs. Buckland, both before and after marriage, made admirable drawings of fossils, some of which were engraved in Cuvier's Oss. Foss. 1824.

[h] The first edition, by William Phillips, was much improved in the second by the additions of William Conybeare.

[i] Palæozoic Fossils of the University Museum, Cambridge, &c.

[k] Silurian System, Siluria, &c. 1837–1867.

[l] Geology of Yorkshire, vol. i. ed. 1. 1829.

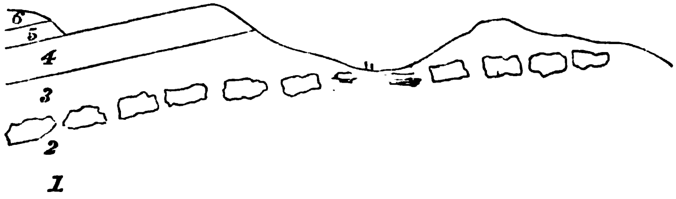

Diagram II. 1. Lias, with pentacrinites and all the Leicestershire fossils. 2. Marlstone with pecten. 3. Clay. 4. Terebratula ('gingerbread'). 5. Clay. 6. White oolite.

With these famous men may stand in the same rank W. J. Broderip, contemporary with Buckland in the same College; for to him we owe the earliest notice of the small mammals of Stonesfield. Later in date was the Rev. H. Jelly of Brasenose College, a student in the school of Richardson and Smith, who was the first to notice the small shells in the ironsand of Shotover Hill. And last, and not less to be honoured than any, Hugh Edwin Strickland of Merton College—a naturalist of rare excellence—a diligent and successful workman in geology, whose loss we still deplore. He repeated and extended the observations of Mr. Jelly on the strata and fossils of Shotover Hill; examined the shell-bearing gravels, and began to collect from the strata near Oxford. To him we owe the first of the two noble specimens of Cetiosaurus which are in the Oxford Museum, found, as he himself recorded, at Enslow Bridge in 1848.

The Bucklandian Collections, to which Mr. Strickland added this remarkable fossil, were in 1848, and for ten years afterwards, preserved in the Clarendon Building. They are now transferred to the University Museum, and a still larger bone of the same species of reptile has been obtained from the same quarry, after an interval of twenty years. It is quite time that the contents of this Museum should be made known beyond the limits of Oxford lectures.

To these conspicuous names of geologists belonging to Oxford and Oxfordshire, must be added that of Dr. Fitton, who presented to the

Geological Society, in 1836[m], a large and valuable series of sections of strata and lists of fossils from the beds below the chalk. In this excellent memoir we find several careful measures of strata on the line from the chalk hills through Hazeley, Garsington, and Shotover to Oxford, and on the line from Stokenchurch through Tetsworth to Wheatley. His notice of Shotover Hill is derived from a communication by Mr. H. E. Strickland. Dr. Fitton also published a notice of the Strata of Stonesfield, which had yielded the jaws of Amphitheria and Phascolotheria[n].

Finally, short memoirs accompanying the sheets of the Ordnance Survey, make us acquainted with the observations recorded during their examination of the region round Oxford by Professor Ramsay, Mr. Etheridge, Mr. Avelyn, Mr. Hull, Mr. Green, Mr. Whitaker, and Mr. Polwhele.

After the publication of the Map of the Strata of England and Wales by Mr. Smith, appeared from the same hand many County Maps, including Oxon, Berks, Bucks, and Gloucester. Dr. Buckland gave in his Reliquiæ Diluvianæ, pl. 27, a broadly-sketched Map of the geological structure of the drainage of the upper Thames. (1821). Dr. Fitton's Map (1836) of the South-East of England shows the country on the south of Oxford. An excellent Map on a large scale of the district immediately surrounding Oxford was published by Mr. Stacpoole of New College; and a few years since the Geological Survey of Great Britain completed the sheets of a larger tract round the city.

Some years since Mr. Whiteaves explored the oolites near Oxford with great success, and discovered many fossils not previously found in them. The catalogues which he composed will be referred to hereafter.

My own contributions to the illustration of the Geology of the country which surrounds my lecture-room may be briefly noticed.

The volume of 'Essays,' written by Members of the University, and published in 1855, contains, among other literary and scientific memoirs, a notice of the Geology of the country round Oxford, the germ of the present work. During the sixteen years of my Professorate, I have been constantly attentive to the points then proposed for consideration. Within this period our Collections have been very much augmented, and some of the groups of organic remains more fully examined. The Essay referred to contained the earliest and fullest catalogue of Stonesfield fossils; but a larger return of the plants and animals of this prolific spot can now be presented.

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[m] Geol. Trans., Series II. vol. iv.

[n] Zool. Jour. III. 1827, 1828, p. 112.

The railway cuttings, and other excavations north of Oxford, give admirable sections of the Bath oolite and upper lias, for comparison with others better known to geologists. Of these, to which my pupils have been often led, I communicated a notice to the Geological Society [o].

The brickyards of Culham afford a singular case of gault resting on almost evanescent lower green-sand, which lies on Kimmeridge clay; circumstances which agree with many phænomena in the neighbourhood in requiring the admission of much waste at several intervals in the sequence of oolitic and cretaceous beds [p].

The fossiliferous sands of Shotover Hill, and the other strata in this moderately elevated ground, furnished a basis for another communication to the same Society; in which the fluviatile origin of the 'iron-sands' is maintained by the aid of drawings and descriptions of Cyrenæ, Unionidæ, Paludinæ, &c. Thus a 'Wealden' deposit, not much differing in age from that of Sussex, is established in a new situation, with concurrent conditions distinct in some respects from those which accompany the better-known deposit in the southern counties. No reptilian or fish remains have as yet occurred in the Shotover sands [q].

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[o] Quarterly Journal of Geol. Society, May 1860.

[p] Ib. Aug. 1860.

[q] Ib. Aug. 1858.

CHAPTER II.

HILLS AND VALES.

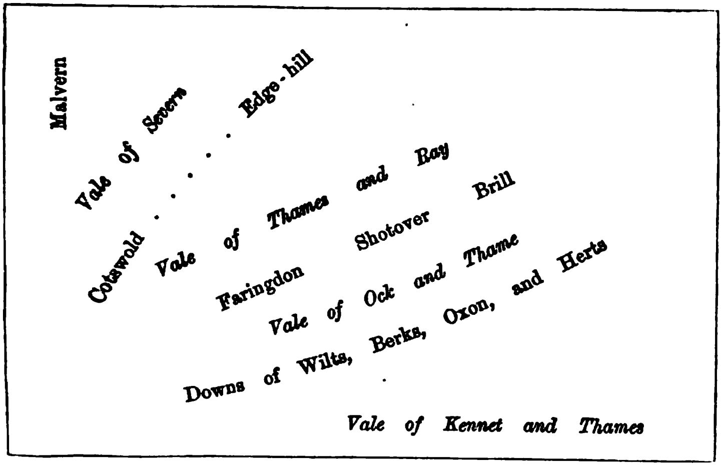
WHAT may be called, in a limited sense, the natural district round Oxford, extends as far as the branches of the upper Thames, and these are all bounded by the high and almost continuous Cotswold Hills of oolite, overlooking lias on the north and west, and by the almost equally high cretaceous strata on the south and south-west. Oxford, though not quite in the centre of the district, if we measure by miles, is strictly so if considered in relation to physical geography and geological structure. Toward this city the greater number of the rivers gravitate; through it is the shortest line of section from the lias to the chalk; near it is the greatest variety of strata, and some strata occur here which are nowhere else so well shown in England. Pre-eminently rich in organic remains as are the ancient strata near Oxford, not less striking are the facts now ascertained concerning the condition of its surface in later geological times, and the perished races of quadrupeds which accompanied the mammoth in his wanderings over hills and dales now vocal with sheep and oxen.

In a larger sense, the district which is open to the Oxford student may include the whole range of the chalk from Wiltshire to Bedfordshire, with the river Kennet, and the vale of the Severn, with the picturesque chain of Malvern. The geological map, Plate I, has been constructed to include the district considered in this large sense. It is not a little in favour of the study of Geology at Oxford, that parallel to the igneous and metamorphic chain of Malvern, are the richly fossiliferous strata of Silurian age, and a great exhibition of old red sandstone; while mesozoic strata of great interest and variety fill all the middle space, and tertiary deposits appear on the southern border. I know of no district of equal area which offers so great a variety of interesting facts to the geological observer, in a country as full of natural beauty and historical associations.

Regarding first the district which includes the drainage of the Thames, and the immediately adjacent region, we find the country marked by ranges of hills, some being formed in almost continuous ridges, others broken into groups of associated heights. These ranges are separated by broad, far-extended vales, a common feature of the more regularly stratified parts of England. In these vales run, with a gentle current, rivers receiving the small streams which descend on either side with greater rapidity. The receiving rivers run more or less parallel to the main ranges of hills, which present escarpments overlooking the vales from the south and east, but on the north and west rise with more gentle and prolonged acclivities. From one of these vales to the next, the collected river runs through a contracted valley, excavated across the dividing ridge; and it is observed in these, as in other cases in England, that at some point above the contracted passage the country has the aspect of a drained ancient lake; as if in fact the passage had been forced by a large body of water which had been gathered above. Not unfrequently indeed the appearance of a lake is renewed by occasional floods of the river. Thus above the contraction in the Thames valley at Iffley and Sandford, spread from time to time the broad waters about Oxford; and, to take a smaller example, Ottmoor, an extensive flat on the river Ray, is not seldom flooded on a great scale above the contraction of the valley at Islip.

Extending our view from the western terrace edge of the Cotswolds, over the broad and fertile plain, watered by the Avon and the Severn, the Malvern hills rise before us with entirely different forms, and stand as the sentinels of another country. Taking these as the true boundary of our geological field, we have the succession of hills and vales represented on the opposite page.

Viewed in profile, or as represented on p. 11 in section, four ridges and hollows appear, parallel to the ranges of outcropping strata, the least conspicuous ridge, that of Shotover, being a series of insulated summits which have escaped the denudation by watery agency everywhere traceable over all this region. The highest points in each range are noted, and the heights are given according to the latest information, kindly furnished by the Director of the Ordnance Trigonometrical Survey.



Malvern Hills.—Taking these alternating hills and vales in order, and beginning from the west, we perceive the Malvern Hills to be marked by abrupt elevation on a line directed from north to south. This is a line of fault. On the west are metamorphic strata, and felspathic and hornblendic rocks of considerable variety,

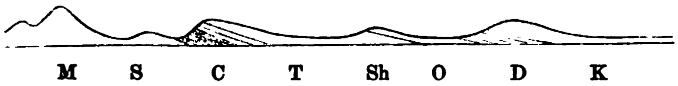


Diagram III. M. The Malvern ridge; its highest point the Worcester Beacon, 1396 feet. S. Vale of Severn and Avon. C. Cotswold range; its highest point, the detached hill of Cleeve, 1084 feet. T. Vale of Upper Thames and Ray. Sh. Shotover range; the highest point at Muswell Hill, near Brill, 649 feet. O. Vale of Thame and Ock. D. The Downs; highest point of Marlborough Downs, 887 feet. K. Vale of Kennet and Thames.

and of great antiquity. These rocks have been generally regarded as of igneous origin, and at one time were thought to have been erupted, after the stratified Silurian rocks were formed, which now cover them in part. During my long examination of these hills (1842–1844) I found this opinion untenable; and it has since been agreed that the main part of the lowest rocks in all the hills of the range is of older date than any of the strata resting upon them unconformably.

Now these later strata are of the Silurian and older than the truly Silurian stages; the grey sandstone of Hollybush and the black shales of White-leaved oak (both near Eastnor and Ledbury) contain Olenidæ, Lingulidæ, &c. of the series of rocks below the Llandilo flags.

Dr. Holl, on considering the metamorphic aspect of the fundamental Malvern rocks, and the undoubted great antiquity of the earliest deposits which cover them, thinks there is ground for referring these lowest rocks of Malvern to the Laurentian series of Canada, the most ancient group of originally stratified deposits which have yet been brought into the geological series. The evidence is insufficient to establish this opinion; but no geologist will hesitate to admit the gneissic and other rocks of North Malvern, at once crystallized and laminated, as belonging to one of the earliest groups of rocks in the British Islands. Some of the gneissic rocks of the North-western Highlands and the Hebrides are shown by Murchison to be of equal if not greater antiquity[a].

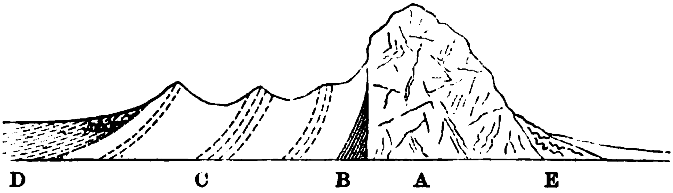


Diagram IV. A. The gneissic rocks of Malvern. B. Cambrian strata. C. Upper Silurian strata. D. Old red strata. E. Permian and new red strata.

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[a] Siluria, ed. iv. p. 163.

Placed in the order of superposition, the rocks of the Malvern Hills and the country adjoining stand as under:—

Mesozoic	Red marls.
	Red and white sandstone.
Palæozoic	Permian conglomerate.
	Coal measures.
	Old red sandstone, marls, and cornstones.
	Upper Silurian strata.
	Lower Silurian strata.
	Cambrian strata.
Metamorphic	Gneissic series of the Malvern Hills, with veins of granite, diorite, &c.

The Malvern Hills, in passing from south to north, rise to the following heights:—

	ft.		ft.
Key's End Hill	617	North of Wind's Point	858
Raggedstone Hill	836	Above Malvern Wells	1178
Midsummer Hill	958	North of the Wych	902
Swinyard Hill	898	Worcester Beacon	1396
Hereford Beacon	1118	North Hill	1318

Standing on the commanding heights of the Malvern Beacons, the natural rampart of Wales, crowned with the war-camps of a long-resisting people, we see this ancient ridge furrowed on its eastern slope by several hollows, running straight to the plain where the ridge is very narrow, but admitting of some winding and division where it is wide. Down these hollows the waste of the surface has been drifted to the lower ground through a long course of time, and may be observed in considerable quantity to the eastward, lying superficially to the depth of a foot or a yard, sometimes mixed with drifted gravel from localities farther north, or with other accumulations of very limited origin derived from the adjoining country.

The Vale of Severn, by these and other proofs, is shown to have had its present general aspect in periods as far removed as the date when the mammoth, rhinoceros, and hippopotamus were roaming about the surface of Britain. Remains of these animals occur in the gravel deposits, and in finer sediments on the course of the now existing valleys, sometimes with fresh-water shells, and other marks of land occupation.

Yet ancient as is this great Vale of the Severn, there is reason to regard it as having been, at least in great part, formed by excavation of the once more extended strata; an excavation which separated the hills of Bredon and Dumbleton from the Cotswold ranges on the east, and stripped the lias from the red marls which it once covered, probably, to the foot of the Malverns. In short, this Vale was not formed (as some have been) by original synclinal structure, or by subsidence, but by denudation through the agency of the sea, and atmospheric vicissitudes. The beautiful outlying hills of Bredon, Dumbleton, Robin Hood, &c., are all monuments of this denudation; 'metæ' (so to speak) left by nature as proofs and measures of her work. The agencies employed will occupy attention in a future page.

The stratified deposits which appear in the Vale of Severn, between the Malvern Hills and the Cotswold escarpment, are—

Upper lias deposits.
Middle lias (marlstone).
Lower lias.
Rhætic beds.
Red marls.

Sections taken across the Vale from the Malvern summit to Bredon Hill present the appearances as shown in Diagram V.

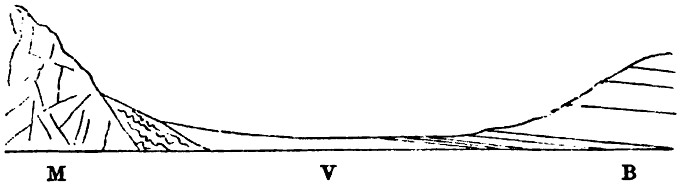

Diagram V. M. Malvern ridge. V. Vale of Severn. B. Bredon Hill.

The Vale of Severn and Avon may be regarded as elevated from 50 to 300 or 400 feet in the district we are considering.

Ascending now the steep western cliff of the ever-breezy oolitic hills, and thinking of the time when it was beaten by the rough

Severn Sea, under the influence of a strong 'south-wester,' such as now assaults the cliffs of Ilfracombe, we find ourselves on the edge of a vast inclined surface, undulated by many winding hollows, among hills continually sinking lower and lower towards the south-east. The westward cliffs, which we have described, are on the whole very woody; thick forests of beech suggesting a doubt whether Cæsar spoke from sure knowledge when he denied to Britain the beech and the fir[b]. The valleys in the Cotswold country are partially wooded, but the hills were, for the most part, originally grassy sheep-feeding surfaces, with no natural wood. The plough has broken up the green carpet, and rectangular plantations have further injured the natural beauty of the 'wold.'

The streams which diversify the surface of these dry hills follow generally the slope of the strata; not very exactly, however, because of many small faults in different directions, and the variously directed lines of weakness which these and the jointing of the rocks occasion. The upper extremities of the longer valleys usually die out obscurely in branching hollows on the dry surface of the inferior oolite; strong springs are found issuing at some distance down the valley. These are sometimes thrown out by faults.

A few of these valleys are continued across the summits of the Cotswolds so as to meet hollows on the western side. Such occur at the sources of the Churn and the Coln: in the former case a double connection of this sort may be traced northwards and westwards from the Seven Wells. In the latter case the same thing occurs, in a very striking manner, at Andover's Ford, from which two hollows proceed, one westward by a low pass to the Chelt, the other northward over a higher 'col' to the Winchcombe brook.

On a greater scale the whole oolitic range is cut through, and a large gap left at the source of the Evenlode, in a broad expanse of lias. A curious low summit is formed between this river and the Windrush, across the ridge of Stow and Iccomb, between Bourton-on-the-Water and Addlestrop, which seems not explicable by reference to causes now in action; and a similar case occurs near Oxford, between Wytham Hill and Cumnor Hurst.

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[b] 'Materiæ cujusque generis, ut in Gallia, est, præter fagum et abietem.' Bell. Gall. v. 12. This passage, strangely enough, would justify our regarding the chestnut as British. 'Abies' probably refers to the silver-fir, well known to Cæsar, not the Scotch-fir, which he, perhaps, never saw.

In all these cases the existing hollow is the work of denudation. The Evenlode drainage may at one time have been like that of the Churn, Windrush, or Coln, enclosed within an oolitic boundary, now wasted away, or marked by only some solitary insular or peninsular hills. Another example is in the Cherwell, whose head waters are gathered among detached hills of oolite once connected into an area as broad as the Cotswold Hills, but probably at no time so elevated as they are.

The course of a valley on these oolitic hills may be sketched freely as beginning upon an undulated surface with several dry branches; then plunging among boldly swelling hills, often richly wooded on their slopes, and forming portions of ornamental ground; lastly, the valley opens widely amidst extensive gravel deposits, which it has brought down into the greater hollow of the Thames.

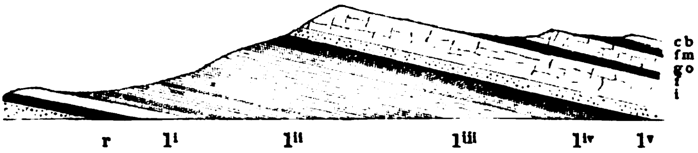
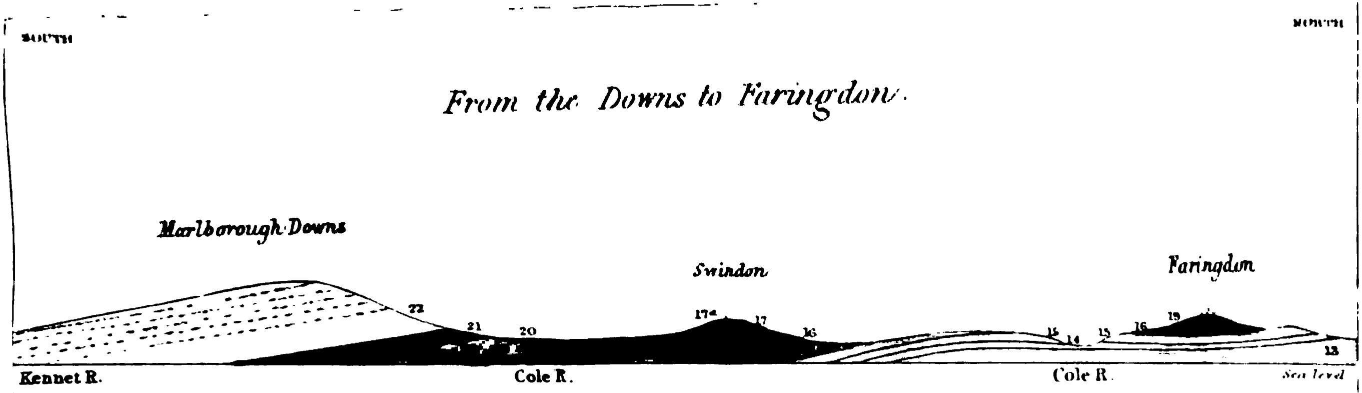


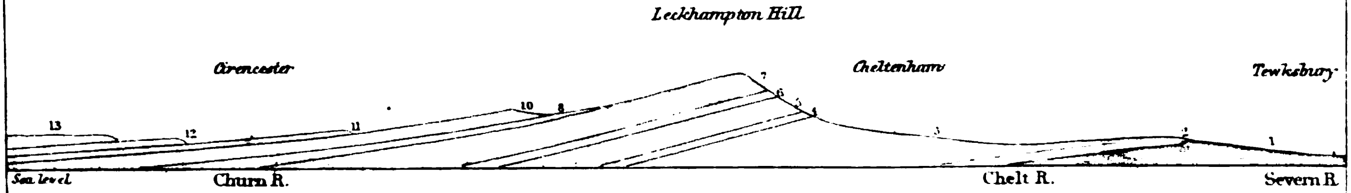
Diagram VI. r. Rhætic or Westbury beds. l^{i}. Lower lias limestones. l^{ii}. Lower lias shales. l^{iii}. Middle lias or marlstone. l^{iv}. Upper lias shale. l^{v}. Liassic sands. i. Inferior oolite. f. Fuller's-earth rock. go. Great oolite. fm. Forest marble, and cb. Cornbrash.

In the Cotswold ranges, and further to the north about Edgehill, though a few steep banks occur along the valleys there are hardly any considerable precipices, even among the woody banks of the Churn and the Coln; no waterfalls are known, nor as yet has any ossiferous cave been discovered, even in the thick oolitic rocks. Perhaps none must be expected; for quarries are opened in almost every part of this stony district, and where the stone is thickest, and caverns might be most likely to occur, the excavations are very extensive—as at Painswick, Leckhampton, and Bourton-on-the-Hill, and about Naunton and Burford.

From the Downs to Faringdon.



From Cirencester through Cheltenham to Tewksbury.



The Strata here represented by numbers are named on Plates V & VI.

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The strata of the Cotswold Hills (see Diagram VI. on opposite page) may be thus classed in succession downwards:—

Cornbrash.
Forest marble group.
Great oolite (Stonesfield slate at the base).
Fuller's-earth group.
Inferior oolite.
Sand of Frocester Hill.
Upper lias (followed in some places by marlstone and lower lias).

The principal hills, or highest swellings of the hills, may be thus enumerated, beginning in the south-west, and following nearly the escarpment edge, for this is generally the highest part of the district:—

	ft.
Birdlip Hill	964
Leckhampton Hill	970
Pewsdown, above Andover's Ford	840
Broadway Hill, highest point	1040

Detached from the main chain are—

Cleeve Cloud	1084
Bredon Hill	979

Further to the east—

Stow-on-the-Wold	771
Long Compton Hill	786
Epwell	742
Edge Hill	718

Turning our attention now to the great transverse hollow in which runs the Upper Thames like a receiving drain, we remark the subjacent stratum to be almost universally the thick Oxford clay, which occasionally spreads out in small detached patches over the cornbrash, the uppermost bed of the Cotswold oolites. These patches are monuments of the former over-extension of the clay, and measures in some degree of the great waste which has happened in the Thames valley. This waste is for the most part of ancient date; for, resting on the surface of the Oxford clay, are broad tracts of calcareous gravel brought down by the Cotswold streams, and deposited in the hollow previously made. In these gravels fresh-water shells occur, with bones of mammoth, rhinoceros, hippopotamus, ox, deer, horse, wolf, boar, &c., just as they have been found to occur in the Vale of Severn. No additions are now made to these gravel beds by the streams which flow in the ancient channels.

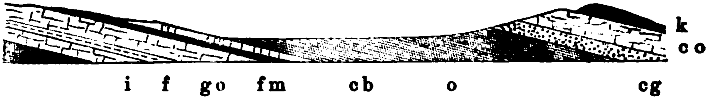

Diagram VII. i. Inferior oolite. f. Fuller's-earth rock. go. Great oolite. fm. Forest marble. cb. Cornbrash. o. Oxford clay. cg. Calc. grit. co. Coralline oolite. k. Kimmeridge clay.

No gravel corresponding in position to that now mentioned is found to have been brought into the vale of the Upper Thames by the streams which enter from the south side—the Rey and the Cole. These streams are so far peculiar, that their origin is not on the sides of the vale of Upper Thames, but begin beyond the next parallel vale (Ock and Thame vale), and pass through the Faringdon ridge before reaching the Thames. Of this more hereafter.

The valley of the Upper Thames is essentially formed in the Oxford clay. It is for a great part of its course only 250 feet above the sea.

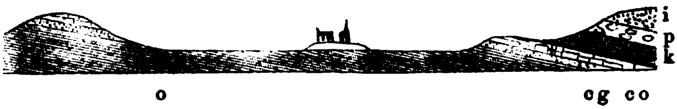

Diagram VIII. o. Oxford clay. cg. Calc. grit. co. Coralline oolite. k. Kimmeridge clay. p. Portland rock. i. Iron-sand.

The next ridge, or rather chain of insulated hills, is the lowest of all, its greatest height being reached near Brill, formerly reputed to be 744 feet, but lately corrected, by the more accurate levellings of the Ordnance Survey, to 649 feet.

Next in height and conspicuous appearance is Shotover Hill, formerly estimated at 599 feet[c], but now determined to be only 567 feet. Cumnor Hurst, on the opposite side of the Thames, marked by the clump of trees, is about 515 feet; Wytham Hill to the north 539, and Stonesheath to the south, about 535 feet. Farther to the west are the prominent detached hills at Faringdon, 505 feet, and the low ridge of Highworth, 442 feet; Cold Harbour, 480; and Wotton Basset, 464. The hill of Swindon may be included in the series, 450 feet.

The strata in this hilly district may be thus classed:—

Lower green-sand of Faringdon.
Iron-sand (Wealden) of Shotover.
Purbeck beds (traces of).
Portland oolite and sands.
Kimmeridge clay.
Coralline oolite.
Calcareous grit.
Oxford clay.

The valley of the Ock, north of the downs of Berkshire, continuous with that of the Thame, north of the downs of Oxfordshire and Buckinghamshire, is but feebly separated from the vale of the Upper Thames, by the somewhat broken line of moderate hills described in the last section. These hills however constitute a boundary between two sets of receiving rivers, and serve as memorials of enormous waste of the surface between the oolitic hills and the chalk downs.

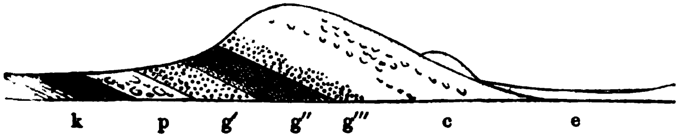

Diagram IX. k. Kimmeridge clay. p. Portland rock. g′. Lower green-sand. g″. Gault. g‴. Upper green-sand. c. Chalk. e. Eocene strata.

It will be shown hereafter that the waste referred to as affecting the surface form was preceded by other operations of the same nature (watery action), which in several parts left no Portland rocks, in others hardly a trace of iron-sand or lower green-sand; so that the true series of the strata is only to be discovered by comparing many sections.

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[c] Sections accompanying Mr. Stacpoole's Map. The difference corresponds to a similar error in the estimate of the height of Oxford Valley.

A considerable part of the vales of Ock and Thame is not more than 250 feet above the sea.

The strata may be thus stated, as observed near Swindon, that hill being regarded as belonging to the vale:—

Gault.
Lower green-sand.
Purbeck beds (traces).
Portland oolite and sands.
Kimmeridge clay.

Looking southward, a range of smoothly-outlined hills forms the horizon line, from all the country round Oxford. These are composed of chalk, resting on feebly-pronounced upper green-sand, which in its turn reposes on a continuous band of gault. Dry valleys, branching over all the surface, descend with uniform slopes and graduated sinuosities, such as to indicate the former action of water. At some point in the downward course springs arise, more or less intermittent in their outflow, and occasionally appearing at points higher than usual up the valley. In the open downs of Wiltshire and Berkshire these valleys are usually called 'bourns.'

The chalk hills between these valleys absorb all the rain which falls, and conduct it to subterranean fissures which form a perennial reservoir of clear water. Wells sunk to the requisite depth never fail to obtain supplies from this reservoir. Thus London draws water from the chalk hills of Herts on the north and of Surrey on the south.

Naturally the chalk hills were covered, as some parts still are, with green herbage suited to sheep farms. In this state they were called 'downs' in Wiltshire, and 'wolds' in Yorkshire. The names remain, though the condition of the surface is greatly altered by the invasion of the plough.

The elevation of the highest summits of the downs is on the whole very nearly equal, from Marlborough Downs to Wendover.

Great waste of the chalk hills is manifest in every part; long-continued watery action has smoothed whatever of inequality once existed, and completed a system of according slopes and windings on which it is a wonder to perceive no effect of rain, and no rivulets. One curious effect, however, of the latest watery action —of that still going on—is the prevalence of flints scattered on the surface of the ground, and, in some places, accumulated into considerable beds. These flints are thus abundant because the chalk has been dissolved away. In parts of the downs of Sussex the quantity of flints lying in a bed on the chalk is very great, and seems to imply that great thicknesses of the calcareous rock have been carried away, so that the flints of many layers, which were originally three feet apart, are now brought together.

We come now to the last of the parallel vales referred to as composing the system of Thames drainage—the Vale of Kennet, prolonged into the great estuarian plain which reaches to the German Ocean.

> 'The Kennet swift, for silver eels renown'd,'

is remarkable among English streams for collecting its waters in a synclinal basin of the chalk. It runs in fact between the downs of Wilts and Berks on the north, and those of Wiltshire and Hampshire on the south. From these downs on either hand the chalk beds dip toward the intervening vale: the highest point in the north, Upcot Beacon on Marlborough Downs, is 887 feet[d]; the most elevated summit in the south, Inkpen Beacon, near Highclere, is 975 feet. From the north the inclination of the strata is gentle, but from the south very steep, a continuation in fact from the almost vertical 'Hogsback' near Guildford.

In the upper part of the Vale of Kennet, about Marlborough, there is abundance of flint gravel; in the lower part, gravel deposits partly covered by peat, the whole presenting more analogy to the Valley of the Somme in Picardy than occurs perhaps along any other stream in England. Below Reading, the low land increases in width between the bordering ridges of chalk; the actual channel of the Thames deviates from the general line of the vale, by entering the northern chalk hills at Henley, and holding in them a picturesque and beautiful course to Maidenhead. Along the whole of this route the borders of the narrow valley are occupied at frequent intervals by gravel composed of flints from the neighbourhood and stones rolled from a distance, and among them lie bones of mammoth, rhinoceros, bear, ox, stag, roe, horse, wolf, &c., the remains of a population for the most part earlier than the pristine human inhabitants of the downs and wolds.

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[d] The famous White Horse Hill = 856 feet.

On the upward sloping borders of the Vale of Kennet flint flakes and stone instruments occur, especially near the numerous mounds and tumuli, which mark sometimes early stages of British history, but more frequently belong to pre-historical periods. If to these indications of ancient occupation we add the magnificent megaliths of Avebury, near the source of the Kennet, it will be evident that in ruder and simpler ages the dry chalk wolds were the favourite haunts of hunters and shepherds, warriors and priests. From these elevated 'speculæ' the far-off foe could be safely watched; by the abundant springs the cattle could be reared; and in the deep woody vales wild-boars and wolves, the roe and red-deer, could be chased by the hound and reached by the stone-tipped spear, long ages before the British Islands became part of the known world.

This abundance of gravel, varied with extensive, mostly superincumbent, deposits of brick-earth and local accumulations of peat, accompanies the Thames to the tide-way, and hides for the most part the eocene deposits, which really extend from Reading to the German Ocean.

Having thus traced a general view of the principal areas of elevation and depression within the scope of our survey, we may turn to a narrower view of some of the special phænomena which are dependent on these physical peculiarities of the surface within the drainage of the Thames.

CHAPTER III.

THE THAMES AND ITS TRIBUTARY RIVERS.

'Tamesis fluviorum omnium, qui Britanniam alluunt, facile princeps mihi in mentem venit.'—LELAND, Præfatio in *Cygn. Cant.*

TAMESIS, the first of the British rivers noticed in Roman story, received its name from the people settled on its banks before the invasion of Cæsar. The first part of the name is found in the descriptive title of many British rivers, as Tame, Teme, Tamar, Thame; the second part seems to mean merely 'water,' as Ouse, Esk, Usk, Wisk, Axe, Exe. The right to the designation will not be disputed by one who has seen the valley under water for many miles during a season of flood.

Such are the elements of Tamesis. How they came to be combined is answered by a rather obvious popular etymology, which unites the names, as nature has joined the streams, of the Thame from Buckinghamshire and the Isis from Gloucestershire. According to this explanation, the name of Thames must have been originally restricted to the lower parts of the river, below the confluence of the Thame, and the name of Isis should be the ordinary title for the main stream above Oxford. It is certainly so called by many authors both of general repute and local knowledge. Leland, who after studying at Cambridge removed to All Souls, Oxford, in his Itinerary calls the well-known spring three miles west of Cirencester in the parish of Kemble, the 'very head of Isis;' he also says 'the head of Isis in Cotteswolde riseth about a mile on this side Tetbyrie.' How carefully he had explored the river, appears by the following words in the Præfatio in Cygn. Cant.:—'Hujus ego aliquando, vel ab ipsis fontibus, ripas, sinus, anfractus, divortia, meandros, denique et mediamneis insulas omneis, curiosissimè illustravi, et memoriæ commendavi.'

Camden, our great leader in British Archæology, a young student in Magdalen College, and afterwards a Fellow of All Souls, Oxford, examined the question of the name of the river, on which, no doubt, he pulled a good oar (1586). Drayton versified the ordinary opinion (1613). Plot speaks familiarly of 'our Isis,' at Hincksey, Oxford, and Ensham, and describes the ill effects of the floods all 'along the Isis from Ensham to Northmoor, Shifford Chimley, and Rothcot.' Still, for all this, it is probable that Isis is a scholarly invention, a fancy of Leland, who, in his poem entitled ΚΥΚΝΕΙΟΝ ΑΣΜΑ[a], or Swan Song, has very freely latinized many names of places on the banks of the river. Starting

> —— 'loco citatus
> Isis quo patitur vadum sonorum,'

he follows 'ripas Isidis virentiores,' and visits 'Isidis insulas amœnas.' Below the confluence 'Tamæ ac Isidis,' at Hydropolis (Dorchester), 'Tamesis' is his name for the river.

Isis had no temple, no worship, and no 'locus standi' or 'fluendi' here, beyond the general meaning of water.

That the true name of the whole stream is Tems, Tamese, Thames, is supported by a charter granted to Abbot Adhelm of certain lands on the east part of the river 'cujus vocabulum Temis, juxta vadum qui appellatur Summerford,' in Wiltshire; and all our historians who mention the incursions of Æthelwold into Wiltshire, A.D. 905, or of Canute, A.D. 1016, tell us they passed over the Thames at Cricklade[b].

It may be noted as somewhat remarkable that not a single village, ford, bridge, or other remarkable object on the course of the stream above Oxford is characterized as 'on Thames' or 'on Isis.'

And yet in the earliest mediæval documents we can refer to, lands are given and boundaries are marked 'juxta fluvium Tamese;' and by 'Temese streame.' Eadmund, A.D. 940, notices Wylfingford, on 'Temese;' in A.D. 942, Æppeltune, not Æsceltune, also called Ærmundes lea, adjoins the 'Temese;' Eadred, A.D. 955, makes us acquainted with Eoccenforda, and Eoccines, Stanford, and Mœgðeforda, on 'Temese;' Eadwig, A.D. 956, mentions Cenigtune on 'Temese,' with a branch called Wulfric's broc. Eadgar, A.D. 968, grants lands at Cumenoran (Cumnor), and gives the 'Temese' as part of the boundary. Æthelred, A.D. 1005, gives lands to the Monastery of Egnisham, 'juxta fluvium qui vocatur "Tamis."' Eadweard, in A.D. 1050, gives to Godwin lands at Sandforda, below Oxford, which are on 'Temese;' in A.D. 1054, the church at Abbandon receives the same lands on 'Temese.' On the boundary of these lands lies what is called 'Sandfordes læce.'

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[a] ΚΥΚΝΕΙΟΝ ΑΣΜΑ, Cygnea Cantio. Autore Joanne Lelando, Antiquario. Londini, MDXLV.

[b] Gibson's Camden, i. 194, ed. 1772.

Thus at several stations as well above Oxford as below it, and far above the junction of the Thame, the river is proved to have borne the name of 'Temese' for 900 years, and no other name is ever assigned to it till Saxon or British names were modified in Greek or Latin verse[c].

Thames Head.—Various in character and, if we may so speak, unequal in dignity are the sources of the many branches of the Thames. To which of them should be given the proud title of the birthplace of the chief of English rivers, if we had the power of choice, might be a ground of fair dispute. Assuming, however, that the western branch of the river, which brings supplies from near Malmesbury, Tetbury, and Cirencester, is to retain the title, we have no difficulty in settling the rival claims of the two forks referred to; the long dull stream from the clays and stony hills near Malmesbury, called 'Swill Brook,' and the shorter, clearer, refreshing rivulet which has been honoured by the name of 'Thames Head,' or 'the very head of Isis.'

The drainage of Swill Brook is separated from that of the Wiltshire Avon by a low summit of Oxford clay, and strata below it, less than 300 feet above the sea.

Swill Brook, a humble Wiltshire brook, has no title to be compared with the vigorous river as once it rose with a full stream out of Trewsbury Mead, and crossed the road from Cirencester to Tetbury; as once it rose at the bidding of nature from the one grand outlet of a broad surface of dry oolite. In a valley now commonly dry, but still occasionally too full of subterranean water to be always dry, rose from immemorial time the clear, full, bright source of Thames, till, in the latter part of the last century, the Thames and Severn Canal drank up the river, to feed its thirsty navigation on the summit level; drank it up by the violent efforts of a steam-engine, which lowered the level of the 'water-bed' in all the adjoining country, so that the natural efflux now takes place half a mile below its former opening. Though diminished and lowered, it still delivers a strong current of sparkling water to a channel almost choked with water-flowers.

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[c] See for authorities quoted to prove the true name of the stream, the Codex Diplomaticus Ævi Saxonici, edited by Kemble; for the reference to which I am indebted to the Rev. J. Griffiths, M.A., Registrar of the Archives of the University of Oxford.

Diagram X. 'The very head of Isis.'—LELAND.

The road from Cirencester to Tetbury is part of the famous straight Cotswold track, called the 'Foss.' It crosses the Thames valley near the source, the latest source perhaps we may say, for the upper part of the valley, now dry, has been in earlier times traversed by descending streams. A large solitary stone stands by the roadside in the valley; and there is a mark of ancient occupation in the circular earthwork called Trewsbury Castle, in close proximity to the once famous source of Father Thames. The source thus named is at a height of 330 feet above the sea. To this low situation the water finds its way from the surrounding uplands of oolite, and a tract of branching dry valleys, from which the transit is easy to the beautiful and deep Vale of Stroud, now traversed by the Great Western Railway, which passes very near to Thames Head.

The supply of water once delivered from the 'true head of Thames' is not easily to be inferred from the now contracted discharge at a point lower down the valley; this being what remains after the leaky summit level of the Thames and Severn Canal has been satisfied. Mr. Taunton states the supply at from 350 to 400 cubic feet in a minute, and never knew it to be less than 200 feet. The water is collected in the joints and cavities of the upper Bath oolite, above the argillaceous bed of Fuller's-earth, which is here 27 feet thick.

Lower down are the Ewen springs, which yield 150 feet per minute on an average, so that fully 500 cubic feet in a minute are commonly yielded by these springs[d] about the very head of Thames.

The water of the Thames is said to have at least two uncommon properties: one is to be subject, when placed in casks and carried to sea, to a clarifying fermentation which yields inflammable gas, and leaves the liquid purer and more appropriate for use than any other water[e]; the other is to freeze at the bottom, when the stream is flowing freely above. Some other examples have been cited of this peculiarity, but this of our own river seems to be the most remarkable and best-attested by repeated observation. Dr. Plot, in his Natural History of Oxfordshire, gives the following account:—'I find it the joint agreement of all the watermen hereabout that I have yet talked with, that the congelation of our river is always begun at the bottom, which, however surprising it may seem to the reader, is neither unintelligible nor yet ridiculous. They all consent that they frequently meet the *ice-meers* (for so they call the cakes of ice thus coming from the bottom) in their very rise, and sometimes in the underside including stones and gravel;' and adds, 'as to the matter of fact, as I cannot but think it hard that so many people should agree in a falsity, so methinks 'tis as difficult they should mistake in their judgments, since I was told by one of the soberest of that calling, that he once knew a hatchet casually fall overboard into the river near Wallingford, which was afterwards brought up and found in one of these ice-meers.'

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[d] Minutes of Proceedings of Institute of Civil Engineers, 1862-1863.

[e] 'The Thames water at sea, in eight months' time, acquires so spirituous and active a quality, that upon opening some of the casks, and holding the candle near the bunghole, its steams have taken fire like spirit of wine, and sometimes endangered firing the ship.'—Plot, Hist. Oxf., p. 26.

The Rev. J. C. Clutterbuck, of Long Wittenham, in a letter to the Royal Commissioners on the Thames Drainage, 1866, presents the results of his personal attention to the phænomenon.

'The formation of ground-ice at the bottom of the stream is another cause of obstruction. The ground-ice, when it rises under the influence of the sun, lifts the stones and gravel to the surface; these masses float down the stream till they lodge in certain localities, and increase the natural obstructions. This ice does not usually form except under a temperature of the air below 20°, as in January 1857 and December 1859.

'Subsequent observation has confirmed the statement that it requires a temperature of 12° of frost, and this usually two consecutive nights. It has been found that the whole body of the water is at 32° at the time when tested.

'The ice when seen at the bottom has the appearance of masses of half-melted snow, and is formed at the tail of weeds, around stones, which it lifts to the surface when it rises, about sunrise, or usually soon after. When examined the mass consists of laminæ and spicula of ice, attached to each other at various angles, as though the formation progressed as new eddies were created by the forming of these laminæ. I have seen pieces of rock eight pounds in weight raised by a mass from the bottom, and carried down the river.

'The formation prevails in the sharp-running shallows, and is *said* not to take place under bridges, nor below the junction of the Thame and the so-called Isis near Dorchester, where the river runs over the upper green-sand in which there are springs. The shifting of gravel and its deposits, especially below weirs through which the ice is carried, is very great; the whole surface of the river sometimes is nearly covered with the floating masses, most of them carrying down sand and stones, and of course depositing them where the ice lodges or is broken up at weirs, &c.

'I am told that the ice forms at the sides of open sluices, which it gradually *fills up*, and around the posts, &c. Every obstruction causes an eddy, and in these eddies the ice forms[f].'

[f] Report of the Thames Commissioners, Appendix I. 1866.

The Churn.—Springing from a higher level than the Thames, and flowing through a longer and more diversified valley, the Churn, or Cern[g], descends from under the crest of the Cotswolds, near Cheltenham, and passes by Cirencester, the ancient Corinium (Caer Corin), the renowned British settlement and Roman camp. Its claim to be called the true source of Thames is admitted by inconsiderately impartial persons who do not reverence the opinions of antiquity. Two main sources indeed contribute to the Churn, both issuing from a dale under the rocky hill three miles south of Cheltenham, called Leckhampton. Does this name contain the British 'Llech,' stone, combined with a Saxon suffix?

These springs rise in a part of the country where formerly no houses were. One of the sources is close to a large farm named 'Ullen,' the other is distinguished as the 'Seven Wells.' The former, probably ancient, name belongs to the more considerable or at least the longer branch, but popular favour has preferred the latter. This favour was not ill deserved by one of the purest sources of the clearest water ever seen, bursting up in joyous activity through joints in the solid rock, in a dell almost buried

Diagram XI. The Seven Wells.

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[g] Sometimes referred to the British root *chwyrn*, 'rapid.'

in foliage. Such a scene in the midst of the dry Cotswold Hills might justify the 'well-flowerings' which still find examples in the equally dry limestone district of Derbyshire. Thanks to 'natural selection,' the springs remain as they used to be, but the beauty of the spot has been greatly altered by a flowery garden, a pretty lake, and growing plantations, more adapted for gay parties from Cheltenham than suited to the grand simplicity of one of the venerable fountains of Father Thames.

Standing near the Seven Wells, we look north-westward toward the steep slopes of Leckhampton, and north-eastward to the rival height of Wistley, each of these prominent points being about 970 feet high. The Seven Wells spring at 650 feet, the Ullen Water issues at about 700 feet. From each the dale continues by an easy pass over to the drainage of the Chelt, the summits being between 700 and 800 feet above the sea.

The two streams unite at Cubberly, which boasts a church and a 'court;' and the River Churn thus constituted runs southward in a pleasant narrow valley (excavated into the upper lias clay), by Cowley and Colesborne, where a few traces appear of a monastic establishment. The valley now contracts, the sides are cliffy and shaded by woods, and at intervals the higher grounds rise in great beauty. Such is the course of the 'nimble-footed Churn,' by Rendcombe Park and the village of North Cerney; and so it continues a romantic and beautiful water to Cirencester. Cirencester was the head station of the great Cotswold tribe known as the Dobuni (Δοβοῦνοι of Ptolemy), whose name perhaps indicates the hilly country in which they resided. Walls two miles in circumference, tessellated pavements, temples, amphitheatres, baths, innumerable works of art, all indicate a great and prosperous city, not a stern camp for war. It was, perhaps, one of the earliest, and certainly one of the greatest, of the Romano-British cities. Passing through a flatter country to Cricklade, the Churn joins on equal terms the stream from Thames Head already referred to. The length of the Churn may be stated at twenty miles.

The outrush of water from the Seven Wells, the beautiful source of the Churn, constitutes at once a small rivulet, which issues from the lower part of the oolite, and soon is found running over lias clay. At Colesborne, in the autumn of 1849, Mr. Taunton found the flow to be 420 feet in a minute. But below this point the stream was reduced by sinking into the open-jointed inferior oolite, and holding for some distance a subterranean course, a frequent occurrence in the districts of the English oolites.

The circumstances attending the flow of the water of the Seven Wells were investigated by the late Mr. Simpson, C. E., for the distance of twelve miles and a half from the source. The curious result is expressed in the following Table; the observations were made in the dry autumn of 1859:—

	cubic feet.
Discharge from the spring head in one minute	11
One-fourth of a mile down the stream	31
Three-fourths of a mile "	61
One mile "	73
Two miles "	105
Two miles and a half "	165
Four miles and three quarters "	312
Five and a half miles "	320

In this part of the valley lias clay is the stratum observed. At this point the volume of the river began to decrease by rushing into the oolites, and at

	cubic feet.
Six miles and a half became	290
Seven miles	235
Seven miles and three-eighths	179
Eight miles and one-eighth	113
Eight miles and seven-eighths	45
Nine miles and three-quarters	33
Twelve miles and a half	30
Fourteen miles and a half	10

Thus the stream was again found to be reduced to less than its original current; nor did it recover the loss in its onward course to join the Thames at Cricklade, twenty-two miles from the source, for it only delivered to the Thames 110 cubic feet in a minute.

Below Cricklade the Thames flows eastward through a broad valley in the Oxford clay, first receiving the little river Rey from the chalk hills near Swindon, and then proceeding to Lechlade. This town stands on a 'lingula' or tongue of land on the north side of the Thames, between the rivers Coln and Leach, which here enter the main stream and bring supplies from the northern hills.

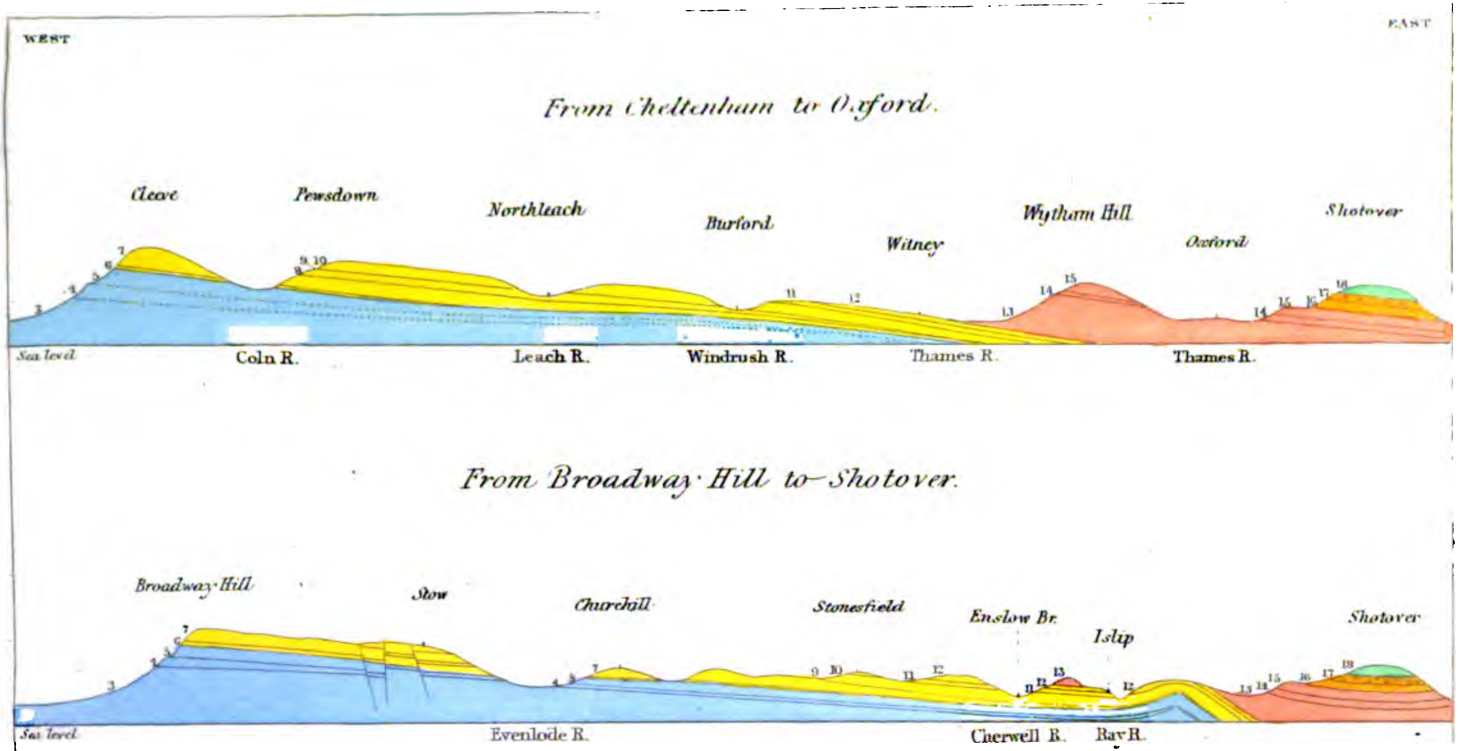
The Coln.—The Coln, a considerable stream, rises within five miles of the source of the Churn, in a valley of upper lias, which separates the lofty oolitic outlier of Cleeve-Cloud from the high ridge above Winchcombe. The village of Charlton-Abbots is seated near its source; not far off, on the east, is an oval entrenchment. The feeble origin of the water is an obscure gathering on the laminated lias clays, scarcely more than a broken thread among water plants. The course of the stream is southward, by Brockhampton, Sevenhampton, Syreford, Andover's Ford, Frogmill, and Withington, at which places it receives strong springs. Here it turns eastward, the lias disappears, and the woodland scenery of Rendcombe on the Churn is repeated in the vicinity of Compton Park and Stowell. At Foss Bridge the great Roman road crosses the river, which below this point gives its name to the parishes of Coln St. Denis, Coln Rogers, and Coln St. Aldwyn's. At Chedworth, on the estate of the Earl of Eldon, a Roman villa has been explored with success.

The dale of the Coln is continued northwards to meet a branch of the stream which descends to Winchcombe. The line of this remarkable valley is on a low anticlinal, as determined by Mr. Hull, and this may probably account for the direction of the valley and the lowness of the pass, which is only 750 feet above the sea, and is overlooked by oolitic ridges from 950 to 1084 feet in height.

Swelled by many fine springs in its course, the Coln, so small at its origin, grows to a considerable stream at Fairford, where 4700 cubic feet in a minute were registered by Mr. Taunton, in March 1854, a time of full water.

Fairford, famous for its church and the coloured glass windows —said (but erroneously) to have been designed by Albert Durer— famous also for the Saxon graves which yielded to Mr. Wylie a rich treasure of arms and implements, glass, pottery and ornaments of many kinds now deposited in the Ashmolean Museum at Oxford—is bordered by the Coln, which from this point carries its full body of water. In some parts of the valley, where it traverses the oolite, part of the stream finds subterranean channels in that fissured and cavernous rock, and is much reduced in dry seasons; a common circumstance in limestone countries. The length of the Coln is about twenty-five miles.

The Leach.—The Leach, which enters the Thames on the other side of Lechlade, is a smaller stream than the Coln, with a shorter



From Cheltenham to Oxford.

From Broadway Hill to Shotover.

The Strata here represented by numbers are named on Plates V. & VI.

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course. Its longest branch springs near Hampnet, a mile above Northleach, where it crosses the great 'Fosse Way.' After leaving Northleach it runs by Eastington, famous for fossils, flows by a camp at Ladborough, crosses 'Akeman Street[h]' at Sheep Bridge, and passes by East Leach, Turville, and Southrop. Northleach, the most interesting place on its course, has a large church with some good sculpture, and several old buildings connected with its former trade in woollens, and its existing grammar school. The Leach, one of the smallest of the Cotswold 'rivers,' has nevertheless its 'Seven Springs' near Northleach, at a height of about 570 feet above the sea. May one fancy the name of the river to contain the British element 'Llech,' slaty stone? for such is often the condition of the oolitic beds on the Cotswolds, though not specially so near Northleach.

The Cole.—At Lechlade, the small river Cole, rising in many branches from the chalk of Marlborough Downs and other strata near Swindon and the White Horse Hill, enters the Thames on the south side. The augmented main stream now continues its eastward course in a broad valley of Oxford clay, receiving few and small affluents till the Windrush, one of its greatest branches, brings a body of water from the extreme range of the Cotswolds.

The Windrush.—This river has several branches. What may be called the main stream begins by three forks far up on the slopes of the high ridge of Broadway and Stanway, beyond and much higher than the sources of the Coln. One of these runs southward from near Snow's Hill, by the open country of Ford and the woody region of Temple-Guiting. At Guiting-Power it receives the united current of several short streams, which spring about Bradwell's Barn, Broadwater, and Rowell, and a small rill from Hawling. From this beautiful and woody region it descends into the deep glen of Naunton, and then emerging into an open valley, passes by Hartford Bridge to the large village of Bourton, seated by the bright and rippling water. Not far below Bourton, another branch comes in, called the Dickler, which springs on the dry slopes of Broadway Hill, in the midst of complicated hollows, where 'Spring Hill' and 'Seven Wells' mark the limited appearances of water.

A few miles lower down, a ramified rivulet, which gathers on the country between Naunton and Sherborne, and flows by the beautiful grounds of Farmington and Sherborne Park, enters the Windrush, and the river proceeds below elevated ridges and woody slopes, by the villages called Windrush and Great and Little Barrington. Taynton succeeds, famous for its excellent building stone, dug a mile north of the village. The town of Burford comes next to sight, with its handsome church built of Taynton stone, in fine preservation; followed by Widford, Swinbrook, Minster-Lovel with its venerable walls, and Witney. From this once very important seat of woollen manufacture the Windrush flows in full stream through a flatter country, by Standlake, Stanton-Harcourt, and Brighthampton, to join the main river. The places just named have several points of interest: one, the deserted residence of a noble family, has magnificent monuments in the church, and interesting memories connected with Alexander Pope; the others have become known to archæologists from some recent discoveries of British and Anglo-Saxon remains, now deposited in the Ashmolean Museum at Oxford. The Windrush is the longest affluent of the Thames: its course may be estimated at thirty miles, without regard to small windings. It is a valuable stream for its many mills, and is attractive alike to the angler, artist, and archæologist. Several old camps are seen along the higher grounds by its course.

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[h] On the Ordnance Map this is called 'The Ikenild Roman Way.'

The Dickler.—On most of the Cotswold streams the long beautiful dales run far up into the thick oolites in many smoothly-winding branches above and beyond any visible source of water. The swiftly-running stream of Eyeford, a small branch of the Dickler, which makes so fair an accompaniment to the picturesque villages called Higher and Lower Slaughter, springs about Swellwold Farm, while above that conspicuous establishment, dry valleys extend for miles with all the naturally-continuous slopes which mark the action of water. How refreshing in hot summer to come to one of these life-giving sources! What thankfulness, what veneration may we not be permitted to feel, while breathing the cooler air around the umbrageous birthplaces of these beneficent waters!

The welcome outburst of the clear swift rill which rushes from the eastern foot of Swell Hill, and in a few hundred yards gives its help to the main stream, is a good example of such springs. A hill of inferior oolite, with traces of the Stonesfield slate, rises 300 feet above the brook. Through this rocky hill the rain, descending by natural passages—joints and fissures very many—gathers into channels, and *flows* (not stagnating in pools) along these to the most easy points of efflux. The repeated flow widens the channels, and the deeper ones become perennial, perpetual, and nearly of uniform discharge. Thus, in the course of long time, the spring-heads may have been transferred lower and lower down the valleys; there may have been rivulets in ancient periods shining in the now dry upland valleys of the Cotswold, and thus in some degree the difficulty of accounting for these valleys may be lessened.

The plain, rather than vale, in which the Dickler yields itself to the Windrush is connected by a very low summit, cut across the high oolitic ridge between Stow and Iccomb, with the valley of the Evenlode, a remarkable feature of local geography.

The Evenlode.—Not much more than a mile from the confluence of the Windrush, the Evenlode joins the Thames. Except in the length of their course, there is little of resemblance in these two rivers. The Evenlode runs in a winding sweep for almost thirty miles parallel to the straight-flowing Windrush, and its sources are near to those of that stream; but its head waters gather in a wide tract of lias, and are divided from those of the Stour, a branch of the Avon, not by a high crest of oolite, like Broadway Hill, but by an obscure low summit of drainage, hardly recognisable by the traveller, between 400 and 500 feet above the sea. The Windrush is a bright, rapid, and picturesque river, with life and activity on its banks; the Evenlode is a somewhat sluggish and often rather unclear brook, which betrays traces of its humbler origin. But it is not void of interest to the geologist and archæologist; for it springs on the line of the 'Fosse Way,' passes in sight of the old 'mercat town' of Stow, and Churchill, the birthplace of William Smith; washes the antique mounds of Foscot, and Bruern Abbey, and glides under Wychwood Forest and the quarries of Stonesfield[1].

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[1] The name Even-lode, Even-load, Even-lad, seems not to be ancient; we must not suppose Even to be a variety of Avon, and therefore of British origin. Lad, Lead, Lode, appear to be employed in the sense of cursus, current, direction; as a mill-lead, a mineral lode.

The river is called Bladaen, Bladen, or Bladene in charters of early date, which record gifts to Evesham [Eovesham] Abbey and Bruern [Bredon] Abbey. Æthilbald, in A.D. 718, grants lands 'juxta fluvium cui nomen est Bladaen, prope vadum cui vocabulum est Dæglesford.' [Ch. Anglo-Sax., i. p. 82.] Offa, in A.D. 772, grants

Before joining the Thames, it receives from Woodstock, Wootton, Glympton, and Heythrop the pretty rivulet called Glyme, or Glime, whose origin is near Chipping-Norton.

The Cherwell.—A broadly-undulated tract of lias, capped here and there by outliers of oolite, gives origin to branches of the Avon of Warwickshire, the Nene of Northamptonshire, and the Cherwell of Oxfordshire. The highest springs of these branches are traceable to the caps of oolitic rock; heavy rainfalls cause rapidly-rising floods from the surfaces of lias, and thus considerable inundations are frequent and hurtful along each of these rivers. The elevation of the summit of drainage, taken at its lowest point, near Fenny-Compton, on the line of passage from the Cherwell valley to that of the Leam, is about 450 feet.

A circle of one mile radius, near Charwelton, includes branches of the three rivers named, to each of which belongs a conspicuous hill, Shuckburgh overlooking the Leam, Arbury the Nene, and Marston Hill the Cherwell. Old camps and entrenchments are frequent in the district; while a few miles to the north-east, and a few miles to the south-west, are the ill-omened but beautifully-situated ranges of Naseby and Edgehill.

The principal source of the Cherwell is at Charwell House, whence it flows to Charwelton, Church-Charwelton, and Woodford. Below this place it receives rivulets from Byfield and Aston, on the west, and a larger feeder from Canons-Ashby and Moreton-Pinkney, on the east. Other branches come in near Trafford Bridge, on the south, and the river, as it may now fairly be called, passes by Edgcott (anciently *Brinavæ*) to Cropredy, both places famous in the Civil War; the former as the resting-place of King Charles I before his first great fight at Edgehill, the latter as the scene of a skirmish between 'hot Rupert' and the Parliamentarians.

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lands 'æt Eulangelade qui situs est in orientali parte fluvii, qui nominatur Bladen;' and, in A.D. 777, marks the course of 'Bladene' by Deilesford, Eunelade, Ceastletone, Cornuelle, Salteford, Deorneford, and Sipton, places all recognised on the banks of the Evenlode. The name of Bladene occurs in the boundaries (landgemæra) of a grant made by Offa in A.D. 779 to Eoueshame, of lands in Dunnestreatun, on the line of the Fosse Way. Bladene is the name of the stream in a charter from Oswold, Bishop of Worcester, in A.D. 969; and again in A.D. 979, in a gift of land at Dæglesford by Archbishop Oswald.

Evenlode is the name of a hamlet near the source; Bladen that of a village not far from the embouchure of the river.

At Cropredy, a branch comes in which supplies water to the summit-level of the Oxford Canal. This branch has two sources; one, near Fenny-Compton, feeds the Wormleighton reservoir; the other, farther to the north, at Prior's Marston, expands in two reservoirs between Bodington and Byfield.

The broadly-undulated region with detached summits now begins to contract to a narrower valley crossing ridges of more uniform elevation. At Banbury this character becomes evident; the country on both sides still yielding tributaries which flow in valleys of lias, with bands of marlstone at some height above the water, and cappings of the lowest portions of oolite in the flat-topped ridges above. The streams which come in on the west, run in small valleys, in places contracted to glens, whose origin is on the high tract stretching from 'Rollrich Stones' to Epwell and Edgehill. One of these, much branched, passes by Wroxton Abbey; another, called Sorbrook, by Broughton Castle; a third springs at Epwell, and flows by Madmarston Camp, a remarkable pentagonal mound on a detached hill; and a fourth runs by Bloxham and Adderbury. Just where the stem of these four rivulets joins the Cherwell, a larger supply is brought from the west, by the river Swere, which divides the two parishes of Barford St. John and Barford St. Michael, and whose sources are close to Great Rollright and Hook-Norton. Deddington stands on the ridge between the Swere and a parallel smaller rill on the south.

Passing now through park-like scenery by Somerton, the Aston villages, Upper and Lower Heyford, and Rowsham, the Cherwell winds its way to Enslow Bridge, before reaching which it leaves the lias and enters the continuous range of the oolites. These strata, here of much less than the ordinary thickness, occupy the stream for about three miles, and then give place to the Oxford clay, in which the water-channel lies till it reaches the Thames.

The Cherwell valley exhibits all parts of the lias, except the lowest parts. To see these, however, we have only to proceed a few miles on the railway, in the direction of Leamington, and stop at the Harbury Station. Here the lower parts of the lias, including the most calcareous portion, which is near the base, are exposed in a large and fine section of the Warwickshire type, resting on the 'Rhætic beds,' as these on the upper red marls which occupy the country to the north-west as far as Leamington.

The Ray.—At Islip a considerable but variable supply comes into the Cherwell, along the channel of the Ray, which has its head-waters about Bicester and Marsh-Gibbon, and flows through the flat plain of Ottmoor, which in floods resembles a lake.

The Thames near Oxford.—The course of the Thames near Oxford is remarkable on several accounts, but chiefly for the uncommon sweep of its channel round the bold headland of Wytham, by which means it seems rather to enter the valley of the Cherwell than to continue in its own. What makes this the more remarkable is the existence of a great hollow between this Wytham Hill and the equally elevated ridge of Cumnor Hurst. If we could imagine a natural dam to have formerly existed on the course of the river, anywhere below Eynsham Bridge, even as far down as Iffley or Sandford, the course of the current might have been through the transverse hollow alluded to between Eynsham Bridge and Botley. There must have been under these conditions a great lake between Cumnor Hurst and Shotover Hill, spreading all round to Yarnton and Eynsham, and far up the Valley of the Thames. A lake only sixty feet higher than the Thames at Eynsham Bridge, would separate Wytham Hill from Cumnor Hurst by a broad, navigable strait. (See Diagram No. XII. p. 43.)

Now, as the contracted passages referred to have been cut through and cut down by water, this lowering of a great natural dam may be in fact the true explanation of the desertion of the old watercourse between the Cumnor and Wytham hills, and of the exposure of the broad level gravel terraces on which Oxford and Yarnton stand. In agreement with this is the manner in which the sandy and gravelly deposits referred to are arranged, for they speak unmistakeably of successive depositions under such conditions as expanded water might occasion, and the occurrence of land and fluviatile shells in the midst of the layers, and in some special nests as it were among them. Far more abundant waters than our occasional floods have at some former time filled the broad spaces where now the Cherwell and Evenlode and Windrush rivers flow into the Thames.

Carrying our thoughts backward in time, it is conceivable that the old Botley valley between the hills of Cumnor and Wytham may have been influenced in its origin and excavation by the same causes as the valley of the Windrush. That valley directs itself right toward this gap in the hills, and in some pre-glacial æra may have been continued into it across what is now the Thames Valley[k]. At some earlier time, the discharge may have been still further west, through the broad depression which reaches from near Fifield to Marcham and Abingdon; a depression from which the Kimmeridge clay has been wholly swept away. Indeed it is almost necessary to suppose such a current in a comparatively late geological period, for how else is the enormous accumulation of calcareous gravel stretching westward from Abingdon to be accounted for? Other openings more or less complete across the 'middle ridge' occur on the course of the Cole, between Highworth and Faringdon, and of the Rey north of Swindon, both streams running through the ridge to the northward.

The most probable general view appears to represent the vale of the Thames above Iffley as a great water ramified among hills, at a level higher than any of the stratified gravels now dry in the vale[l], and that water of similar character occupied the low ground above the contracted part of the river course at Clifton and Dorchester, spreading westward toward the Vale of White Horse, and eastward toward the Vale of Aylesbury. From the boundary hills on all sides the streams, descending with force for very long periods of time, transported the loose detritus, and deposited it abundantly near to their embouchures. Not exclusively, however; because in such lakes as have been supposed the wind-force would create much disturbance, and, in some places, shift the gravel into long continuous banks.

The broad plain of Ottmoor would become a lake, if the narrow part of the valley of the Ray at Islip were to be effectually barred by the crossing of the rocks, as once, no doubt, it was. Still, from time to time Ottmoor is heavily flooded, and heedless pedestrians may have to try the depth of the water, as happened to myself a few years ago in crossing toward Studley.

That a lake once existed here is likely, but that the present broad surface is its dried bed, is not a safe supposition. The river may have flowed through a contracted lake in the midst of a wider marsh, and innumerable inundations may have spread a level sediment over the area. These effects may have grown less and less by the wearing down of the obstacles on the channel, and by what appears to be certain, a great reduction of rainfall since the immediately post-glacial times.

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[k] The gravel beds of Botley and North Hincksey may have been brought by it.

[l] The gravel at Oxford is nowhere more than thirty feet above the valley, but it rises to a greater elevation about one and a half miles to the northward, and preserves this elevation to Yarnton.

Port Meadow, and other apparently flat surfaces on the course of the Thames, suggest the idea of lakes formerly existing in these situations; it is very likely that such may have existed, and been drained by the wearing away of natural dams, as for example at Iffley and Sandford below Oxford. As the dam was lowered, the marginal parts of the old lake would first be uncovered, and the other parts in succession; and all would be smoothed and levelled by deposits from inundations. The surfaces would be for a long time marshy, full of aquatic plants and shells of lacustrine type. This is very observable in Port Meadow, wherever drains are cut to a moderate depth. In these the gravelly uneven bed of old lake or river channels is met with.

The Ock.—At Abingdon, the Ock, a not inconsiderable stream, brings water from White Horse Hill and the vicinity of Faringdon and Wantage. It occupies the broad Vale of White Horse, principally excavated in Kimmeridge clay, with detached hills of Portland stone and sands.

The Thame.—The flexuous Thames receives some other additions, running by Clifton Hampden, where the lower greensand makes bold cliffs of conglomerate, to Dorchester, when the Thame unites itself to the now great river; its spring-heads being far off in the lower chalk of Tring and Prince's Risborough and the oolitic rocks of Quainton and Brill.

At Dorchester was seated the first Bishop of Wessex; at an earlier date was founded the Roman camp (Durocina), on or near the site of a more ancient British settlement, allured to the pleasant water side, and defended by the mounds on Wittenham Hills. *Dwr*=ὕδωρ=water, in the Roman name assures us of its having been previously noted by the Britons.

From this point by Wallingford, Goring, and Pangbourn to Reading, the course of the Thames is a scene of quiet pastoral beauty—a green valley winding among softly-swelling mounds of chalk. But it is not less full of painful memories of disastrous civil war. Who can tread the rich fields of Chalgrove, or muse by the bright stream of Kennet, without thinking of Hampden riding away to a lingering death, and Falkland struck down at the first onset of Byron's Horse?

'Nulla dies unquam memori vos eximet ævo.'

The Kennet.—The drainage of the Kennet is included in a great natural basin of the chalk of Berkshire, Wiltshire, and Hampshire, within which the nearly-straight stream, flowing from west to east, gathers many small branches, which themselves are the stems of more numerous smooth dry valleys. The lowest parts of this summit of drainage, 500 to 600 feet, are toward the west, where the chalk is nearly cut through by ancient watery action. The highest parts of the border on the north (White Horse Hill and Marlborough Downs) reach 856 and 887 feet, and on the south (Inkpen) 975 feet.

In the eastern part of its course the Kennet enters the lowest tertiaries, and discloses above gravelly and sandy layers, near Newbury, a considerable surface of peat, containing remains of animals of the post-glacial age, not so ancient as the mammoth, whose remains occur in the gravel. This peat is a mark of stagnant water, like that in the Valley of the Somme, which in some other respects the Vale of Kennet resembles.

Among these remains are those of the beaver, and a cranium of man has been mentioned. Remains of the beaver have also been found in a peaty district near Chippenham, bones of rhinoceros tichorhinus in a corresponding tract near Wantage, and the wild-boar and long-fronted ox were obtained, with a human cranium, near Swindon. Close to Oxford, on the course of the Cherwell above Magdalen College, were found in peaty gravel teeth of elephas primigenius, and bones of horse, ox, deer, wolf, &c. On the whole, however, marshes and peat grounds are not to be described as frequent in a large range of country round Oxford.

CHAPTER IV.

PHYSICAL GEOGRAPHY.

Summits of Drainage.—We designate by the term 'summit of drainage' the line on the surface from which rain, falling vertically, does run or might run on one side to one valley, on the other side to another. 'Watershed' is a word of equivalent meaning, and in the north of England it is often the limit of extensive property, and is sometimes called the 'heaven-water' boundary.

The valleys of the Thames thus considered present some curious points for remark.

And first with reference to the valleys of other river systems, as the Avon of Wilts; the Severn; the Avon of Warwickshire; the Nen of Northamptonshire; the Ouse of Bedfordshire.

Towards the Wiltshire Avon that western branch of the Thames called Swill Brook is directed, and on its course the low summit of drainage may be traversed at points not exceeding 300 feet above the sea.

The 'true source of Thames' in Trewsbury Mead is in the descending course of a valley which extends beyond it a few miles, and allows of an easy passage by a short tunnel to the Water of Stroud, which descends to the Severn near Newnham. The summit of drainage is here about 500 feet above the sea.

Beyond each of the springs of the Churn, under Leckhampton Hill, a dry dale extends to a low 'col,' from which a rapid descent conducts by the channels of the Chelt to the plain of Severn. These summits are about 750 feet above the sea.

More curious even than this is the long, straight line of the Upper Coln from Andover's Ford meeting the similar straight line of water-course which descends from Charlton-Abbots to Winchcombe. This summit of drainage, between high hills of oolite, is 750 feet above the sea. But from Andover's Ford, on the Coln, 540 feet above the sea, the road to Cheltenham passes over a comparatively low transverse neck of land, 600 feet above the sea, through which, if the Severn Vale were full as once it was, it might throw its stream into the drainage of the Thames.

The summit of drainage between the Windrush and the Avon is the high cliff-edge of the Cotswold, toward which, on the eastern side, we rise by a long ascent, which continues to the very brink of a steep descent. There is here in fact hardly any distinct col or depressed passage across the summit, so that, like the Leach, this may be regarded as purely a Cotswold stream, which has no rain-channel connection with the feeders of the Severn. This summit of drainage is, in some places, 900 feet above the sea.

Very different is the case of the Evenlode, which collects itself near Moreton-in-the-Marsh on a broad low summit only 450 feet above the sea, meeting there a branch of the Stour.

Meeting branches of the Avon of Warwickshire and the Nen of Northamptonshire, the Cherwell watershed is about 450 feet above the sea. The Ray drains ground much lower, so that one may pass out of this system into that of the Bedfordshire Ouse by an easy summit, 300 feet above the sea. The Thame drainage is passed at a height of 450 feet, and that of the Kennet at 550 feet.

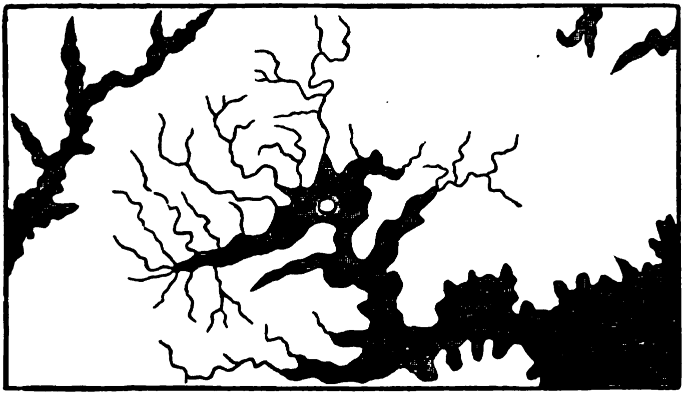

Diagram XII. Land submerged 250 feet.

If now we represent on a map the condition of things when the sea was at higher levels than now, a theory established by certain evidence, the results are very instructive.

In Diagram XII. the sea is admitted to a height of 250 feet above its actual level, in the valleys of the Thames, Severn, Nen, and Ouse, the rivers being marked only in connection with the Thames. At this level, the Thames Valley would be (must have been) a vast estuary, with a sea-loch up the Kennet Vale; straits between the chalk hills of Chiltern and Lambourn; lochs right and left up the Thame and the Ock; straits near Abingdon; and again lochs right and left up the Ray and up the Thames; narrower and far extended sea-channels up the Severn and the eastern rivers.

Under these conditions the Cotswold rivers may have delivered abundant detritus, and formed gravel and sand beds of great extent on the sides of the long loch of the Upper Thames, while from the chalk hills considerable quantities of flints would be collected on other parts of the shores.

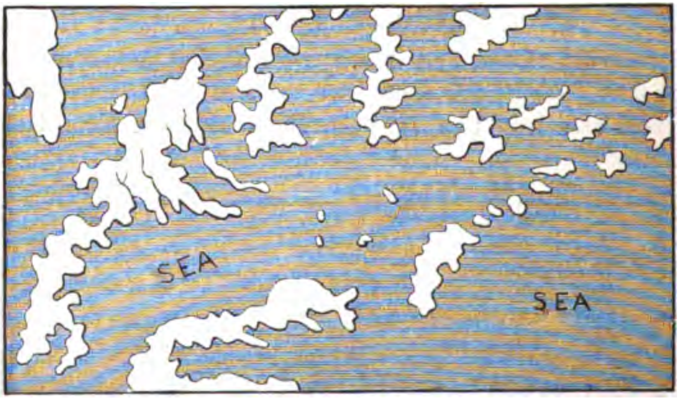

Diagram XIII. Land submerged 500 feet.

Taking a different level, raising the sea 500 feet, we have the aspect of land and water, as in Diagram XIII.—a series of islands branching out in a wide expanse of ocean; the Cotswolds broken up into many digitated masses; the Thames basin confluent with the Avon of Wilts and the Avon of Warwick; no limit to the sea on the eastward; still the straits of the chalk remain at Pangbourn; islets of the oolite near Oxford; and other straits appear, especially on the Evenlode and the Cherwell, through which a communication is opened to the great midland sea which reaches to the hills of Lincolnshire, Derbyshire, and Shropshire. More than half the area of land in the Oxford district is now submerged.

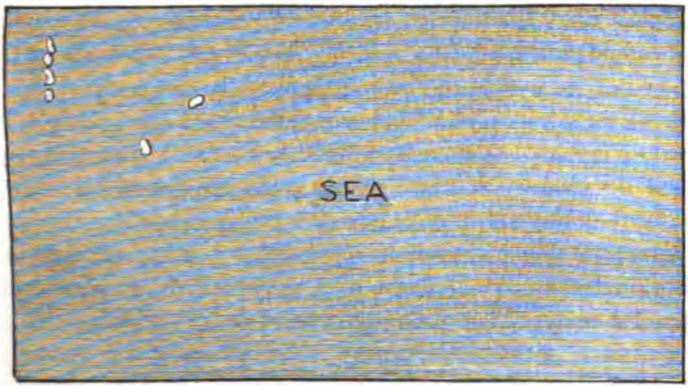

Diagram XIV. Land submerged 1000 feet.

Finally, raise the level of the water to 1000 feet, and nothing of land remains but the higher peaks of the Malvern Hills, Cleeve near Cheltenham, and Broadway near Evesham. At intervals during the elevation, from 500 to 1000 feet, the straits of Evenlode and Cherwell might admit ice-rafts in abundance from the northern seas, and allow of violent wave action on the parts of the land brought successively to the condition of sea-bed. Thus may the red pebbles of Warwickshire have been transported to the Vale of the Thames, and many important effects of watery violence occasioned. The events here sketched have really occurred; the sea-line has been changed in the manner stated, in a comparatively late part of geological time, as it had often been changed before. In the periods which it is agreed to call pre-glacial, glacial, and post-glacial, the land which is now Britain was made to sink (relatively to the sea-level) so as to be in great part submerged, and again it has been by a reverse process restored to nearly, but not quite its former elevation. There is no evidence of this being a cataclysmic process, but much reason to treat it as a gradual subsidence and a gradual resurgence of the land. Great and inevitable watery violence accompanied these movements, and by them every part of the land was wasted, during the long periods while the depths of the sea were such as to permit of the effect of breakers on the shore and currents on the bed. Both while rising and while falling, the water hammered against the shores and dredged along the channels; wasting the surface, reducing the heights, digging out the valleys, and spreading detritus over submarine plains.

Following continually the retiring sea, rivers often swept away the traces of its action, or covered them with fresh deposits. Atmospheric vicissitudes, rains and snows, heat and cold, disintegrated the rocks; carbonic acid aided in dissolving them; new phænomena replaced the older ones, new features were impressed on every hill and every hollow; and thus our land surface, as we see it, exhibits in every part the modifications produced by what may be called the 'ordinary action' of daily causes, these being superimposed on broader and greater features generated by elevation and depression on a great scale, accompanied by powerful waves and strong currents of the sea.

Supply of Water in the Thames.—The drainage area of the Thames above Oxford (exclusive of the Cherwell) is about 600 square miles. The rainfall may be taken at 2½ feet in depth in a year. The total quantity of cubic feet falling on this surface in a year

$$=2\tfrac{1}{2} \times 600 \times 5280^2 = \text{cubic feet } 41{,}817{,}500{,}000;$$

and in a minute = cubic feet 79,507.

The dry-weather summer-flow, being observed at Wolvercot and Wytham, = 11,620 cubic feet in a minute; this is proportioned to 4·38 inches out of 30 inches.

The dry-weather winter-flow (without rain), being noted at the same place, = 22,624 cubic feet; this is proportioned to 8·55 inches out of 30 inches.

The flow in rainy weather being taken at 35,498 cubic feet; this is proportioned to 13·35 inches out of 30 inches.

And the floods being estimated at double the rainy weather quantity, = 70,996 cubic feet; this is proportioned to 26·70 inches out of 30 inches.

The summer and winter measures of the perennial spring-water give us an average 6·46 inches out of 30 inches.

If moderate rainy weather be supposed to occur for one-fifth of the year, this will add to the above $\frac{13{\cdot}35-6{\cdot}46}{5} = 1{\cdot}38$ inches;

and the floods, taken at one-twelfth of the year, will add a further quantity, $\frac{26{\cdot}70-13{\cdot}35}{12}=1{\cdot}11$ inches.

Thus, on the whole, we collect $6{\cdot}46+1{\cdot}38+1{\cdot}11=8{\cdot}95$ inches out of 30 inches as the proportion brought by the Thames from the upper drainage to Oxford. A like proportion may be assumed for the Cherwell.

Half the quantity is spring-water filtered through oolitic rocks, and on this account considerably charged with carbonate of lime, and thrown out by clay beds containing bisulphide of iron, or sulphates of lime, from which probably arise the small quantities of salts containing sulphuric acid which are observed.

The dry-summer flow at Surbiton, near Kingston, has been estimated by Bateman at 380 million gallons daily; by Simpson at 400 millions; say 65 million cubic feet, four times as much as the flow at Oxford. The drainage area may be taken at 3600 square miles, or six times that of the upper drainage of the Thames. $\frac{65{,}000{,}000}{3600}=18{,}000$ cubic feet per square mile in a day.

By the observations of Mr. Stacey at Wolvercot and Wytham, the upper drainage of the Thames yields in a day of dry summer weather 24,000 cubic feet per square mile.

The perennial supply, therefore, of the whole drainage of the Thames, taken at the lowest, seems to be about three-fourths of that of an equal surface of the upper drainage. As the rainfall in the lower part of the Thames Basin is less than in the upper part by about one-fourth, we might have expected the perennial springs to be less productive, though it is to be remembered that very large surfaces of dry chalk contribute to this supply, and that a large extent of gravelly and sandy surface absorbs the rain and stores it below the surface.

Rainfall.—The flow of water in the Thames, a matter of more than local interest, is maintained by a rainfall which varies from 34 inches among the high western hills to 24 inches on the lower eastern declivities. It is to the south and south-westerly winds, which strike the Cotswolds while still damp from the Atlantic, that we owe the larger quantity of our rain: as these winds pass to the eastward, and there in a somewhat dryer state encounter lower hills, the measured fall is reduced. On the eastern coast of England the rainfall may be averaged at 20 inches, while on the coasts of Wales it is from 30 to 60 inches, and amidst the high mountains about Snowdon and Cader Idris, twice as much has been collected in a year[a].

The distribution of rain in the different months may be judged of by the Register kept with great exactness at the Radcliffe Observatory in Oxford. Taking five years, from 1861 to 1865, we find the records for the several months to be much more nearly equal than is usual in England:—

	1861.	1862.	1863.	1864.	1865.	Mean.
January	0·66	2·45	3·17	0·97	3·05	2·06
February............	1·90	0·28	0·68	1·44	2·08	1·27
March..............	1·68	5·46	0·67	2·47	0·97	2·25
April	0·69	2·27	1·41	1·63	0·91	1·38
May................	1·36	3·74	0·94	2·15	2·19	2·18
June	3·12	2·24	3·41	1·01	3·52	2·66
July................	5·15	1·75	0·66	0·47	2·79	2·16
August	0·60	1·75	2·65	0·79	3·09	1·78
September	1·94	2·16	2·72	2·94	0·18	1·99
October	1·58	2·89	2·96	1·56	5·39	2·87
November	3·07	0·99	2·01	2·32	2·58	2·19
December	1·65	1·43	1·08	0·51	1·96	1·32
Sum................	23·40	27·41	22·36	18·26	28·71	

Mean Annual.......... 24·03 inches.

Prevalent Winds.—During the same period rain came to us with the different winds in the following proportions:—

	1861.	1862.	1863.	1864.	1865.	Mean.
N.	2·26	5·93	0·75	3·17	5·83	3·59
N.E.	2·56	3·39	2·05	2·16	0·62	2·16
E.	1·62	0·88	0·92	2·34	2·44	1·64
S.E................	1·85	1·81	2·63	3·39	7·70	3·48
S..................	8·59	7·96	9·30	6·83	9·48	8·43
S.W.	11·41	13·49	6·86	5·07	3·28	8·02
W.	3·57	5·59	1·61	2·03	2·12	2·98
N.W.	3·01	2·05	0·78	1·24	2·63	1·94

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[a] See Symons's British Rainfall, 1868. The maximum in Wales in 1858 was 115·10 inches, on Snowdon.

Here the greater rainfall with southerly and south-westerly winds, at Oxford, is very manifest; these two directions yielding more than half of the whole measured quantity.

The number of days on which rain fell with these various winds stands in even a higher ratio for the same five years:—

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
1861…………	11	10	7	11	46	77	35	17
1862…………	20	18	13	19	54	79	45	18
1863…………	9	10	10	12	58	60	23	7
1864…………	18	7	10	34	56	33	14	10
1865…………	12	4	16	38	54	28	17	12
Means……	14·0	9·8	11·2	22·8	53·6	55·4	26·8	12·8

If the path of the wind over Oxford be laid down for a whole year, from the Observatory Register, it will appear that at the end of the period the atmosphere, after drifting in various directions, has been displaced to the north-eastward a few thousand miles.

The line of this annual drift has been determined by the Radcliffe Observer, in the five years already referred to, as under:—

1861………………………	S. 51° W.
1862………………………	S. 51° W.
1863………………………	S. 40° W.
1864………………………	S. 19° W.
1865………………………	S. 15° W.

in which a tendency to deviate eastward seems to be indicated in the last three years[b].

The mean temperature of Oxford is something under 50°. From 1862 to 1866 it averaged 49·8°, the highest being 50·5°, the lowest 49·0°. During the same period the highest monthly mean was 62·9° (July, 1865), the lowest (January, 1865) 36·8°.

The mean temperature of evaporation differs from the air, on an average of five years (1861–1865), 2·78°. This small difference may seem to justify the opinion, that the Oxford air is a little damper than the average of the same latitude in England; but it is not uncommon with us to experience extremely dry weather with differences between the dry and wet bulb of

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[b] In 1866 the mean direction was found to be S. 12° W.

6°, 7°, and 8°, the instruments being carefully placed in the shade; on the other hand, there are many days when only a small fraction of a degree distinguished the dry from the wet bulb.

Sites of population. Supply of water.—The earliest settlements among a pastoral people must have been near springs of water, or on the course of rivers, or by the side of lakes: nor have the changed circumstances of society at all diminished this primary dependence of man and his cattle upon the supply of wholesome water. On the contrary, society has grown fastidious, and chooses to bring its supplies from distant sources, even to the banks of the rivers on which towns are flourishing. One of the great questions for the Roman administration has been revived in our day, under far more difficult conditions, and the springs of all the rivers of England are upon their trial in the great struggle for the pure element. If it could be proved that the fall of rain is less than it formerly was, and that artificial circumstances of any kind may influence the quantity, the extent of woods, the system of drainage, and the kind of land cultivation may be brought into the complicated problem.

The effects of artificial drainage are twofold. Surface drains, straighter and clearer than the old ditches—direct cuts instead of winding brook-channels—must carry off rain and snow-water more rapidly than was formerly the case. Thus some water may be abstracted from springs, but not much. Thus floods must happen more quickly after rain, and may gather in greater force in the broad expanses of the valleys. But deep drains, which draw down surface-water, and cause it to be slowly discharged in almost continuous small underground rills, have an opposite effect; they augment the subterranean streams, and feed, as by new springs, the permanent flow of the rivers.

In any case the basin of the Thames may for a long period be the only source of supply to London; and as, on every stream which contributes its share to this river, every day is increasing the local demand for water, the prospect of a sufficient current being abstracted from the main stream becomes less and less encouraging.

Almost all the villages, and a great part of the detached farms in the Cotswold country, are seated by springs of clear, but usually rather hard, water. The hardness is commonly from carbonate of lime. Carbonate of iron occurs not rarely, and sulphate of lime is seldom wholly absent. Chloride of sodium is well known to exist in almost every spring. As an example of a spring over-rich in carbonate of lime, the Hincksey water may be mentioned, which has been brought to some of the colleges in Oxford. At Somerton, on the Cherwell, a strongly petrifying spring is mentioned by Plot, and another at North Aston. Another case near Oxford occurs above Marston Lane; and Dr. Plot narrates the petrifying effect of the well-water pumped at the Cross Inn, near Carfax.

Chalybeate springs—the iron-salt being a carbonate—are frequent, as at Stow, Northleigh, Shipton-under-Wychwood, Nether Worton, North Weston, Heddington, and Astrop, south-east of Banbury, which was noted as curative some years ago. They are from the base of the inferior or great oolite or marlstone.

Sulphureous waters occur at Idbury, Chadlington, Churchill Mill, Banbury, Deddington, Clifton near Deddington, and a bog in King's Sutton parish; a saline water is mentioned at Cumnor.

Fords.—In examining the course of many English streams, the places where considerable roads cross are often marked by the epithet 'ford;' as Oxford, Andover's Ford on the Coln, or simply Ford on the Upper Windrush. One who looks at these last-named places may wonder at the designation; for an active schoolboy can overleap the stream, which is besides not deep. Yet, on further reflection, he will admit the justice of the title, and discover in it matter for curious research. In the wilder state of our country, the little streams, 'wandering at their own sweet will,' made an hundred little twists in the course of a mile; nay, even now on the Evenlode and Windrush, this is a common fact. These parts of the channel were often, and still are, in marshy and reedy clays, with failing banks and no secure bottom. For the 'essedæ' in war, or the 'wain' bearing salt; for horses and men, and even sheep and oxen, these were no fit passing places, however small the stream. Fords, then, were sought, where a firm rock made a solid floor, or hard gravel offered equal security. Thus at Oxford, the gravelly bed of the valley, at Ford on the Windrush, and many other places on the Cotswold waters, a portion of the oolitic rocks presents the natural condition which was desired. A 'ford,' in fact, did not imply originally a place where the water is shallow, while on either hand it is deep; it is the 'trajectus,' the 'road' across a stream, and probably is of British origin: 'ffordd,' in fact, is a road, path, or way; while 'rhyd' is really a ford—a curious example of adopted words with exchanged meanings.

Waterfalls can hardly be said to occur in the whole of the Oxford district; a circumstance which might have been affirmed from considering the nature of the chalk, oolite, sandstone, and clay which compose the strata. For these are not so unequal in their resistance to waste as to allow of much local undermining of clay and much overprojecting of rock, the main causes of the frequent waterfalls among palæozoic strata. Rapids, however, alternating with pools, favourable to the angler, occur often where the varying beds of oolite cross the upper branches of the Thames, as on the Churn, the Coln, and the Windrush; and advantage is taken of the more rapid descents of the stream for the establishment of many water-mills.

Forests, Heaths, Indigenous Plants.—In many parts of England large, open, unenclosed, and thinly-peopled districts, with no more than the ordinary, or less than the ordinary clothing of trees, are called 'forests,' as if exterior to or beyond (foris) the more settled and cultivated country. Some of these may have been anciently woody tracts, like the 'hursts' of Sussex. In the district round Oxford the great forests of Wychwood and Whittlebury are remarkable examples of mixed sheep-downs and pleasing glades, among extensive masses and irregular groups of really forest trees. Much wood still grows on the Chilterns, and some of the great parks of the Cotswold have been formed amidst or in close adhesion to earlier forests, as Oakley, Rendcombe, Stowell, Charlbury, Woodstock. In other parts vast woods of native growth, and that ancient occupant or immigrant the beech[c], occupy the uncultivable steeps of the hills, as about Birdlip and Stanway; while Shotover and Brill have lost their trees, and almost their title as forest hills. Perhaps my attention has not been critical, but I do not remember to have seen any considerable surface of heath in this whole district. Calcareous soils, like those of the oolitic hills and the chalk downs, are not suited to the growth of erica or calluna, nor are the clay vales better adapted to them. Some tracts, as Churchill

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[c] The noble elm which fills the valleys of Wessex and Mercia, and penetrates to Northumbria, can be traced back three centuries; the chestnut eight; no date can be assigned for the arrival of the beech. These trees are not found in old alluvial deposits, nor have they been employed in ancient boats or burials.

Heath, may have deserved the name, but cultivation has obliterated many marks of natural selection and human neglect.

One of the heath-plants, Calluna vulgaris, is mentioned by Walker, in his 'Flora of Oxfordshire,' as growing at Eynsham Heath, a gravelly soil; another, Erica tetralix, at Binfield Heath, a sandy tract beyond the scope of my examination; and a third, Erica cinerea, at Checkendon, south-east of Wallingford, on the sandy covering of the chalk.

Orchidaceæ, favoured by the calcareous soil, are unusually plentiful. Most of the British species are found within the drainage of the Thames, and specially in the oolitic and cretaceous areas. Among these the musk orchis, the fly, bee, and spider ophrys, lady's-traces, and the bird's-nest, twayblade, may be noted.

Among water-plants which add beauty to the Cherwell and the Oxford Canal—now less disturbed by boats than formerly—and to the many half-deserted channels in the Vale of Thames, we may notice the water-lilies, bog-bean, and feather-foil. Among meadow-plants, the snake-lily and the snow-flake claim attention, as beautiful dwellers in the Vale of Cherwell and Thames: the former at Standlake above Oxford, as well as in Magdalen and Cowley Meadows, and near Reading; the latter below Oxford, and near Reading.

The distribution of plants in the Oxford district will probably engage the attention of Professor Lawson.

Ancient Roads.—The part of Britain of which Oxford is the centre fell at an early period of the Roman invasion under the sway of the regular provincial government. Oxford was unknown, even in the Trojan tradition which amused the historians of later days[d]: but the great camp on the Churn speedily became the centre of Roman influence, the point of convergence of Roman roads, the abode of luxurious citizens, decorated with baths, temples, and amphitheatres. Durocornovium, Corinium, Corin, Caer-Corin, Corin-Ceaster, Cyrencester, is on the track of the great Fosse Way from Moridunum (Seaton) on the Dorsetshire coast, through Aquæ Solis (Caer-Badon, Bath) to Ratæ (Leicester) and Lindum (Lincoln). This famous way was crossed at Cirencester by a conspicuous road called Akeman Street, which connected the Vale of Gloucester with the great western route called Watling Street.

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[d] Brian Twyn, in his Antiquitatis Academiæ Oxoniensis Apologia (1608), adopts Greekelade (Cricklade), and Latinlade (Lechlade), as the pre-Oxonian seats of eloquence and literature in Britain!

From Durocornovium parted the great road to Londinium, through Spinæ (Speen), and Calleva (Silchester), in the country of the Atrebatii, a place signalized by the great range of its yet standing walls, and the extent of its interior streets and houses, lately explored with taste and liberality by the Duke of Wellington and Mr. Joyce.

From the road last mentioned more than one track leading to the Icknield Way is traceable, across or at the foot of the chalk downs to Durocina (Dorchester) and Wallingford on the Thames, and thence by Camboritum (near Cambridge) to the camp of Venta Icenorum, near Norwich. And from Durocina, northward, ran a road now called the Portway, by Shotover Hill, to Ælia Castra (Alcester), Brinavæ (Edgecot), and the station supposed to be Bennavenna or Isanavatia, near Daventry.

These are for the most part roads which connected considerable military stations and towns of magnitude; there are others which seem to have just claims to equal antiquity, though not for the same objects. Such are the continuous trackways which keep along the higher ridges of dry land, and hold their course among fortified hills and long mounds of tumuli, with occasional megalithic remains. Such tracks may be followed from the deep Stroudwater valley, along the edges of the hills, with glorious views over the rich Vale of Gloucester to the mountainous regions beyond, by Birdlip and Leckhampton, to the great gap at Andover's Ford; from which again the hill-paths lead along the Stanway crest to Broadway and the extended promontory of the Ilmingdon Hills. Everywhere points of hills cut off by defensive dykes; often small inclosures or camps; frequent mounds, more suited for watching living foes than inclosing departed friends. Everywhere the marks of such a period as that which came to an end when the great Silurian chief yielded to the Roman power.

It is generally supposed that the numerous earth-mounds on the edge of the oolites from Bath toward Edgehill were, if not constructed, employed in the war of Ostorius against Caractacus. The words of Tacitus, 'inter Aufonas,' are supposed to limit the fortified line. Camps, like those of Sodbury, and Uleybury, and Standish Hill, may readily be accepted as Roman works; but many of the other stations look more like posts of temporary occupation, fitted only to resist a marauding party from the Vale. The Silurian power, if not the Silurian people, was active in the Vale of Gloucester, while the Dobuni were masters of the hills. Hill-men and Dale-men were terms of defiance and watchwords of fight at the merry-makings in the Cotswolds, as late as the last century.

A very ancient track runs from the Evenlode up the Chastleton Hills, among camps and 'barrows,' to Rollrich Stones and the tumuli about Traitor's Ford and Brailes; and then continues along Edgehill to the Cherwell Valley. A westward continuation of this road may be marked to Stow; from which high—probably very old—settlement on the Fosse Way several roads pass toward the Vale of Gloucester. These roads from Stow, and others on the Cotswolds, often climb (as if by intention) to ridges of elevated country, and ascend to the highest points of land, from which the largest views could be had; often, at these high points, the roads cross, guarded by a turnpike. One reason may have been, a feeling of more security on the open wold than in the shaded valley; but the main cause of this peculiarity is probably the desire to travel on dry ground—an advantage rather too frequent on the oolitic terraces between the branches of the Thames.

'Rollrich' Stones, the most remarkable megalithic monument in the district, have suffered injury since they were described by Camden and Plot; but, till within the last few years, the three parts of which they consist were all fairly preserved. The 'Old King,' the 'Whispering Ring,' and the 'Five Knights,' appear in the annexed cut (p. 56), reduced from the representation in Plot's Oxfordshire (Plate XVI. figs. 1, 2, 3). The situation is on the line of ancient hill-road between Chastleton Barrow and Traitor's Ford —a road which may have served for the soldiers of Ostorius as they marched along the frontier of the Dobuni 'inter Aufonas.' On the north of this road, close by an old quarry, stands the 'Old King,' a mass of stone, nine feet above the ground, which may be the remains of the rude effigy of a warrior looking downward. South of the road is the circle of unequal stones (fig. 2), about thirty in number at present. In the drawing of Plot twice as many appear. In the opinion of the country-folk, no man can count them truly—the same tradition as at Stonehenge. The ring was supposed to be bewitched: the witch lived at Long Compton.

Toward this place the king was marching, in hopes of winning the English crown, when the witch transformed him to stone.

> 'Let the valley rise and the hill go down,
> That I may see Long Compton town;
> If Long Compton I could see
> Then king of England I should be.'

The 'Whispering Ring,' within which a sound uttered at one side is heard on the other, 'by placing the ear to the ground,' was composed of the soldiers; and the separate group of five stones (fig. 3) were the King's 'five knights.' This group was really a 'cromlech:' it seemed as if one broad stone had roofed in a cell, with four uprights.

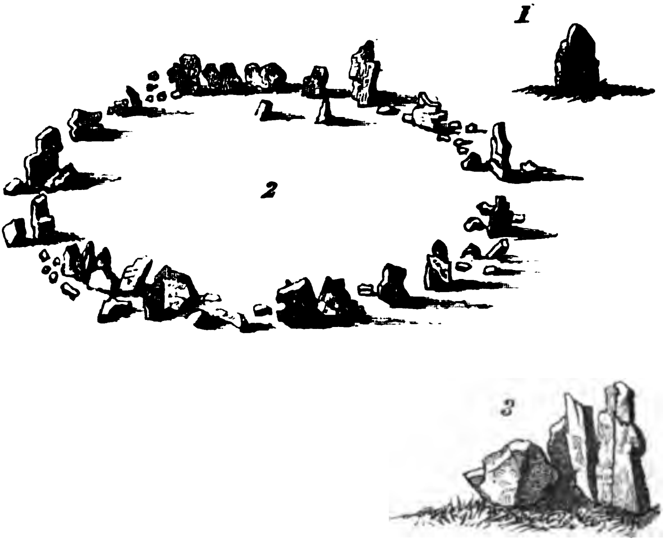

Diagram XV. Rollrich Stones, from Plot's Oxfordshire.

The stone was obtained in the immediate vicinity. It is a coarse, shelly oolite, which occurs somewhat irregularly among thinner calcareous beds.

The name is usually accepted as indicating the kingly title, or kingdom of Rollo, and the monument thus becomes Norwegian, or popularly Danish. But it is probably of much higher antiquity, the Danes being often credited for dykes, forts, and tumuli, whose origin had been forgotten before the days of Rollo.

The 'Whispering Ring' is about 100 feet in diameter; the 'King' stands 100 yards to the north; and the 'Knights' did stand at 350 yards to the south-east; but they have been overthrown by the farmer.

On Speed's Map of Oxfordshire, more than two centuries and a half old, and Morden's Map, about a century and a half old, I find, near Eynsham, the words 'Rolrich Stones,' and some attempt to mark their place. These are doubtless the stones mentioned by Plot at Stanton-Harcourt, near a tumulus.

'As for the stones near the barrow at Stanton-Harcourt, called the *Devil's Coits*, I should take them to be appendices to that sepulchral monument, but that they seem a little too far removed from it; perhaps therefore the barrow might be cast up for some *Saxon*, and the stones for some *Britans* slain hereabout (and vice versa) at what time the town of Eignesham, about a mile off, as Camden informs us, was taken from the Britans by Cuthwolf the Saxon. . . . They are about eight feet high, and near the base seven feet broad; and they seem not natural, but made by art, of a small kind of stones cemented together, whereof there are great numbers in the fields hereabout.'

The stone here referred to, a natural conglomerate of late geological date, was employed in building the fine old church of Stanton-Harcourt. Plot's conjecture of the concurrence here of Saxon and British remains, was unexpectedly supported by excavations made a few years since at the neighbouring village of Brighthampton, which disclosed a British settlement with many pit-houses, and Saxon burials with abundance of ornaments, fictilia, instruments, and weapons. These are now in the Ashmolean Museum.

CHAPTER V.

THE OLDEST ROCKS OF ENGLAND.

THE Oxford district, regarded as a field of geological study, may be extended beyond the drainage of the Upper Thames to the grand line of ancient rocks which runs from Malvern to Bristol. In this area, though in patches of small extent, nearly the whole palæozoic system is observable; the whole series of mesozoic strata makes its appearance; and a portion of the eocene strata comes into view near Reading. Over these regular strata we find, pretty extensively spread, a scattering of northern drift; and in several of the vales and plains on the course of the rivers lies a considerable quantity of local drift, mostly gravel and sand, with here and there deposits of peat. There are few minerals of value in the district, except iron ore, but great plenty of building-stone, limestone, glass-sand, and brick-earth.

Thus within easy distance of Oxford, nearly a complete series of English strata can be well examined, the effects of disturbance and the peculiarities of plutonic eruption considered, and the operation of surface-waters fully worked out. The outlines of land and sea at different epochs, the situation of estuaries, possibly the course of primæval rivers may be determined, and maps be drawn of the palæozoic, mesozoic, and cainozoic ages of this part of the world, quite as good in their way as those which Ptolemy constructed for the Isles of Britain soon after their appearance in the records of Roman story.

The oldest stratified rocks of England, probably older than any in Wales, perhaps as old as any in Scotland, are found in the Malvern Hills, within two hours' of Oxford. These hills rise from the Valley of the Severn, in a solitary ridge to which there is really nothing very similar in the British Islands; the nearest analogues, by geological position and mineral character, being perhaps the felspathic rock groups of the country about Charnwood

Forest—very ancient rocks certainly. These Malvern Hills meet us, on our journey from Oxford, like a wall, and differ in every way from all the strata which surround them.

The strata which compose the principal part of the Oxford district have almost uniformly dips to the south or south-east; and their 'outcrops' range from west to east, or from south-west to north-east. On the whole, these outcrops may be said to be on courses from W.S.W. to E.N.E., and to be gathered in three principal but unequal ranges of hills alternating with parallel vales. The hilly ranges are on the whole composed of firmer and the vales of feebler strata; the term 'firmness' being taken to signify the resistance offered by any mass of rocks to the disintegrating action of water, in falling rain, flowing rivers, or rushing tides and currents of the sea.

The Malvern Hills range from north to south. What may be said to be their dip, marked by a succession of rolls, is westward, under palæozoic strata, while low down against their eastern slope lie the mesozoic strata. On the western side, very ancient strata, with great and frequent marks of disturbance through pressure; on the eastern side, broad tracts of comparatively modern strata, free from disturbance. The lowest and oldest of these mesozoic strata are of the Bunter (oldest part of the new red) or Permian age; they are conglomeratic, and partly derived from the Malvern rocks against which they in places rest[a]. The Malvern Hills stood up, then, before the sea-currents accumulated these materials, though not to their present height.

Passing now to the westward, we find among the disturbed strata, almost in contact with the Malvern rocks, the old red sandstone; and in the Forest of Dean, on the west of the line of the Malverns, the carboniferous limestone and coal measures involved in the system of movements; so that we arrive at a near approximation to the date of one of the great disturbances of the Malvern region and a large range of country both north and south of it, viz. after the coal formation, and before the Permian (or Bunter) deposits. This is confirmed by the coal-workings of Newent and Kingswood, where new red deposits (Bunter and Keüper) rest tranquilly on disturbed strata of the carboniferous age.

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[a] Phillips, Memoir on Malvern Hills (Geol. Survey of Great Britain, vol. ii. part 1), p. 111. The reader may also be referred generally for information on Malvern to Sir R. I. Murchison's great work, Siluria; and for special notices of the metamorphic rocks to Dr. Holl's Memoir, Geol. Soc. Proceedings, vol. xxi. p 72.

But this is only one part of the long history which can be traced among the Malvern rocks. Passing downwards through the old red sandstones, conformable, or nearly so, to the Silurians, and still sinking lower and lower in these,—in other words, ascending the stream of time,—we find toward the base of the upper Silurians vertical strata of brecciated or conglomerated rock, with sandy and micaceous laminæ, full of fossils—the fossils being Silurian, the stony fragments derived from the Malvern rocks[b]. The whole is like what an accumulation of detritus, such as now is gathered at intervals on the slope of these hills, would become if it fell into a sea rich in corals, crinoids, and brachiopoda. The Malvern rocks, then, stood up in the sea and were subject to waste before the later Silurian ages.

Nor is this all. By continuing the search into earlier periods we discover among the older strata on the western side of Malvern proofs of unconformity among them, and deficiencies in the series of deposits, such as clearly to indicate movements of the whole region before the deposit of the May Hill sandstones, and again before the very earliest of the Cambrian rocks which are found along the Malvern chain.

That which was disturbed in the pre-Cambrian age was the old rock of Malvern—there is no known case of older earth-movement in the British Isles—and unless, by some unexpected discovery in the north-western Highlands, the geological epoch of the disturbed 'fundamental' gneiss there should be carried back *by fossils* to a still earlier date, we must rank the Malvern rocks as among the earliest of the solidified products of the globe. And those products were, at least in part, stratified. They were stratified: the traces of stratification remain. They were not, as far as we can perceive, accompanied by organic beings: there are no fossils; there is no limestone among them, such as might indicate that fossils had been. They are metamorphic in the sense usually attached to this term when we speak of gneiss; they are, in fact, gneiss, that quasi-granitic rock, so very variable from place to place, but so very generally expanded below the whole series of fossiliferous strata.

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[b] This important observation was made by my sister in 1842.

They were stratified: the materials were collected in water, and arranged under the influence of water. Whence came these materials? In the strata whose earlier aspect has not been changed by metamorphism, we have no difficulty in replying; partly from wasted coasts and wasted lands; partly from organic secretions, precipitation of marine salts, mineral sublimations.

Only the first of these conditions can be made in any way to fit with the case in hand. Before the earliest rocks of Malvern were still more ancient lands and shores. What was then the solid earth? Shall we suppose a cooled granitic crust, easily disintegrated, to have been the parent of gneiss and mica schist? That these rocks as we now see them have been again half or more than half reconverted to granite? That granite is the recurring term of a series now anterior, then succeeding, now the wasted parent, and again the renewed product of gneiss? Settle this as we may, land and sea existed in this part of the globe before the earliest rocks visible in the British Isles.

Was the land, and especially was the sea inhabited? There is no record. Only in another part of the world, among strata of gneiss as old, if not older, than these of Malvern, has one solitary organic body been found[c], viz. in the 'Laurentian' gneiss of Canada. There being no limestone in the Malvern gneiss, there is but little chance of discovering organic remains. There is no history, tradition, record, or monument of this mythical period. Those who in modern times have studied the 'theories of evolution' which for a century and more have amused the 'philosophy of nature,' are aware of the importance of this lost evidence. They who adopt these theories must do so under the enormous logical difficulty of replacing unknown records by imaginary terms founded on the theory which requires them to be real.

'Etiam periere ruinæ.'

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[c] Eozoon Canadense. This foraminifer or sponge has not obtained its certificate,

'Proved by the ends of being, to have been,'

without protest. See Geological Proceedings for papers by Carpenter, Dawson, King, Rowney, and others.

THE FIRST OR GNEISS PERIOD OF MALVERN

is marked by the appearance of laminated deposits, in which mica or hornblende, or both, occur with felspar and quartz. The laminæ are very distinct and flexuous about Malvern Wells, on the eastern side of the ridge. Rocks of the same system about the Wych are less distinctly formed of granular minerals; others allied to them in the North Hill are, on the contrary, granitic in their aspect. Containing, as they do, hornblende very generally as an ingredient, most of these rocks of the North Hill were termed syenite by Mr. Leonard Horner, Sir R. Murchison, and myself; but the latest observer, Dr. Holl, regards them as of the same metamorphic origin as the unquestionably gneissic strata of Malvern Wells, and compares them in point of date with the very old gneiss of Canada—the Laurentian series, in which eozoon occurs—the earliest known or supposed form of life.

Traversing these rocks in veins, or somewhat irregularly dispersed in masses among them, are very largely crystallized mixtures of quartz and orthoclase felspar, quartz and mica, felspar and mica, or quartz, felspar, and mica, with or without hornblende. Such may be seen on the ridge above Great Malvern, in the road to the Wych, where also occur bands of silvery or golden mica, greenish hornblende, and a kind of grey talc. Epidote is a frequent mineral in the gneissic and syenitic bands over North Malvern and West Malvern. Another beautiful variety of rock is formed by the mixture of rich broad-plated hornblende and a felspar of white or pale reddish tint, not distinctly crystallized, certainly not orthoclase, and probably less rich in silica. To this rock the name of 'diorite' may be given, according to the nomenclature of Cotta. It has usually been placed in one of the vague groups of syenite or greenstone.

Segregation from a fused mass is often regarded as the cause of these irregular mixtures; in several cases, however, the posteriority of felspathic and granitic veins to the masses which they traverse is quite certain, but they are of earlier date than any of the Silurian strata.

The old gneissic, felspathic, and hornblendic rocks of Malvern are variously jointed and fissured; in some cases the divisional surfaces are so related to one another as to produce octahedral and prismatic shapes, which emulate regular crystals. Some of these are represented below; and I may say in general that they fairly approximate to secondary forms of anorthic felspar, common hornblende, and augite. It is conceivable, and in fact appears on examination to be true, that in the seemingly confused crystallization of the masses, planes of easy divisibility may have been sometimes occasioned by the greater than ordinary prevalence of particular cleavage-parallels through small masses of rock. They occur in quartzo-felspathic, dioritic, and aphanitic compounds, and the forms are different in each case.

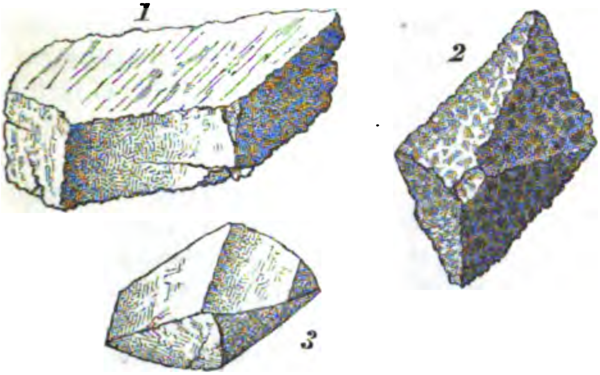

Diagram XVI.

1. Crystalloid mass of large-grained quartzo-felspathic granite, with very little mica, and veins of epidote. The felspar is red, and well crystallized; the quartz grey. The form of this specimen appears to be on a type of albite.

2. Crystalloid mass of large-grained dark hornblende and reddish felspar; the former well crystallized, the latter but slightly so. This felspar is anorthic. One of the octahedral faces is of recent fracture, the others are natural faces. The form is derivable from a prism of hornblende with lateral solid angles replaced.

3. Finer-grained mixture of the same minerals.

Thus we have in the Malvern ridge of very old rocks:—

Gneiss, varying from a distinct crystallized mixture of felspar, quartz, mica, and hornblende (North Hill), to an obscure, grey, much-fissured mass, in which the component parts are hardly distinguishable (about the Wych). In respect of lamination very unequal; often no sign of it. An intermediate condition is common about Malvern Wells. In some parts (about the Hereford Beacon and Wind's Point) the laminæ of crystallized hornblende are very remarkable, and offer some resemblance to the dark gneiss of the Hebrides.

Granite in veins and what appear to be separate masses; the felspar is often very largely crystallized reddish orthoclase; the quartz is of considerable size; the mica varies in quantity, always of pale tints. No tourmaline; no garnet.

Syenite, meaning by this a kind of granite with hornblende. It is often of fine grain, and obscurely laminated.

Diorite, a felspatho-hornblendic rock, the felspar not being orthoclase; granulation often very large. The felspar is white or pale red, and lies amidst the hornblende much as in large-grained ordinary greenstones. Its crystallization has not been determined. The hornblende is often of that sort sometimes called rich, on account of a certain effect of light reflected from its planes (North Hill).

Besides these, which are all well-marked rocks, we have frequently greenstones, felspatho-hornblendic, or felspatho-augitic compounds, the felspar not being orthoclase, and not distinctly crystallized. It is difficult to determine whether these are to be distinguished into Diabase, as containing augite, and Diorite, as containing hornblende, or which is the easiest but not very satisfactory method, grouped under the title of Aphanite. The distinctions are not of much importance in geological reasoning.

Felstone occurs in the hill sides above Little Malvern, but no true porphyry.

Quartz rock was formerly seen in the road-cutting of Cowley Park, but it has been removed by 'improvements' of the road.

Serpentine, or rather a trappean rock approaching to it, is found in the slopes above Little Malvern and in other parts of the southern hills.

Mineral veins are scarcely known in the Malvern Hills, and there is no trace of slaty cleavage.

Among minerals we may notice:—

Mica in veins of considerable thickness, in the ridge above Great Malvern.

Talc in a vein cutting through gneiss, in the Wych.

Epidote in small crystals as of frequent occurrence, though in small quantities, on fissured surfaces and in the interior of the crystallized gneissic beds.

Graphite, so it appeared to be, was found in the midst of the Malvern rocks, about the centre of the tunnel on the railway to Ledbury.

Copper pyrites and copper carbonate occur above West Malvern.

Sulphate of baryta occurs in veins which traverse the gneissic rocks of the North Hill. The date of these veins may be as late as the great faults to be noticed hereafter.

CAMBRIAN PERIOD.

The remote period of the formation of gneiss, with its associated granite, syenite, and hornblende rock, came to an end by means of a disturbance of the sea-bed, which left a very unequal surface for the following stratification, and occasioned a great unconformity; such that, in the northern part of the chain, the May Hill sandstones lean against the Worcester Beacon; the purple sandstones are nearly vertical on the western face of the North Hill, while the black shales and Hollybush sandstone are confined to the southern hill-sides. This is the first great movement certainly traceable in the region of Malvern.

The particular circumstances of this early movement can be but dimly seen through the mist of subsequent phænomena. We may probably affirm that it was one of considerable local disturbance, because the strike of the gneissic laminæ is by no means uniform in the different hills which compose the chain; nor is it as a rule even approximately parallel to their common direction, but sometimes appears to cross it. If in imagination we replace the now-elevated Silurian and Cambrian strata, so as to make them nearly horizontal, we shall have an uneven surface of gneiss mixed with granitic and other rocks; the lowest part as a whole in the southern part of the chain: and it is on or against this depressed part only that the oldest of the palæozoic strata are seen to rest.

One may believe therefore that the Malvern ridge of felspathic rocks was in some degree sketched out at so early a date as the epoch of this first disturbance of the sea-bed, and that it even then stood in part above the waters.

The Cambrian or second Malvern period is marked by the deposition of marine sands, now consolidated to stone, somewhat peculiar in composition, and of a greenish tint, as if derived from decomposed rocks of the old Malvern types. Sometimes an appearance is presented which has suggested the idea of volcanic ash, erroneously as it appears to me. Occasionally small fragments and pebbles occur which may be regarded as of Malvern origin. To account for this deposit, suppose the old rocks to have been once far more extended northward, and to have been wasted by atmospheric and sea-action; let the prevalent currents have been from the north; sand-banks would have been formed along the flanks and round the south end of the hills; and the loops may have been continued to the eastern side, but that is concealed from observation.

These sandbanks are the Hollybush sandstone. Its thickness is not less than 600 feet; it may be much greater, for its real base is not seen; there may be other strata below; but we have no means of discovery, or even of conjecture. It is poorly marked by life remains: possibly fucoids; certainly annellida and brachiopoda.

The following short list is given by Dr. Holl[d]:—

Annellida.	Scolithus.
	Trachyderma antiquissima. *Salter.*
	Serpulites fistula. *Holl.*
Brachiopoda.	Lingula squamosa. *Holl.*
	——— another species.
	Obolella Phillipsii. *Holl.*
	——— two other species.
	A small unascertained bivalve.

This fauna has a very primordial aspect; but so small a group of fossils can hardly be held to prove more than general analogy to some part of the Cambrian series of strata. The absence of trilobites is remarkable. The catalogue will probably be augmented by further search, but it must be a tedious search.

The next great deposit, confined to the southern part of Malvern, and following in a parallel loop the curve of the Hollybush sandstone, is a nearly uniform black shale, of great thickness—about 500 feet[e]—enclosing some bands of 'trap,' composed of felspar and hornblende, and having other masses of like nature on its upper boundary. I could never see any dykes of this rock actually traversing the shale, but there can be little doubt of the fact, after inspecting the outbursts at Fowlet's Farm and Bransill Castle. The rock is an ancient lava, consolidated for the most part underground, or under the sea. One might, however, mistake the ferruginous and cellular stone of Fowlet's Farm for the sub-aërial reliquiæ of a volcano in Auvergne. This great deposit of shale must have been formed in calmer and probably deeper water than the Hollybush sandstone; and so we get the true idea of the physical change going on, viz. a continual subsidence of the sea-bed interrupted by occasional volcanic outbursts.

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[d] Geol. Journal, 1865, vol. xxi. p. 89.

[e] Dr. Holl increases my estimate to 1000 feet.

The first discovery of fossils in this black shale was made by myself, after a hard day's work, in 1842. Since then Mr. Hugh Strickland, Miss Lowe and her sister, and other diligent observers have added to the originally small catalogue. At present it stands thus, including Dictyonema socialis, which was found by Mr. Symons in the upper part only[f]:—

Hydrozoa.	Dictyonema socialis. *Salter.*
Annellida.	Only uncertain traces.
Crustacea.	Conocephalus Malvernius. *Phillips.*
	Olenus bisulcatus. *Phillips.*
	,, humilis. *Phillips.*
	,, spinulosus. *Phillips.*
	,, pauper. *Phillips.*
	Sphærophthalmus pecten. *Salter.*
	Agnostus Maccoyi. *Salter.*
	,, princeps. *Salter.*
	Cytheropsis.
Brachiopoda.	Lingula pygmæa. *Salter.*
	Obolella Salteri. *Holl.*
	Spondylobolus.
	A minute bivalve.

The inference from this list, which, however, contains several species peculiar to the locality, would seem to place the black shales on the parallel of the Tremadoc or Upper Lingula flags. Further discoveries may be expected, but nothing is likely to deprive this Malvern shale of its claim to rank among the oldest fossiliferous strata of England.

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[f] Holl, Geol. Journal, xxi. p. 91, gave the list nearly as here presented. I have added three species which are in the Oxford Collections.

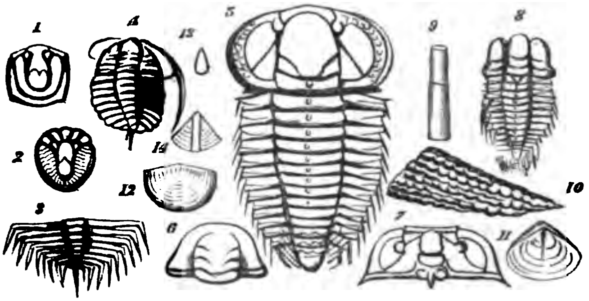

Diagram XVII. Fossils from the Cambrian strata of Malvern.

1. Agnostus Maccoyi. *Salter.* Magnified twice.
2. Agnostus princeps. *Salter.* Natural size.
3. Sphærophthalmus pecten. *Salter.*
4. Olenus pauper. n. sp. *Phillips.* Magnified twice.
5. Conocephalus Malvernius. n. sp. *Phillips.* Magnified twice. The posterior extremity indistinct. (See C. innotatus. *Barrande.*)
6. Olenus scarabæoides. *Wahlenberg.* Magnified twice.
7. Olenus bisulcatus. *Phillips.* Magnified twice.
8. Olenus humilis. *Phillips.* Magnified thrice. The posterior extremity indistinct.

†9. Serpula fistula. *Holl.*
10. Dictyonema socialis. *Salter.* Natural size.
11. Obolella Salteri. *Holl.*
†12. Obolella Phillipsii. *Holl.*
13. Lingula pygmæa. *Salter.*
14. Spondylobolus.

The species marked † are from the Hollybush sandstone, the oldest fossiliferous rock of Malvern; the others from the lower part of the black shale, except Dictyonema socialis, which is from the upper part of the same. The specimens are in the Oxford Museum.

Several other trilobites are indicated by fragments, and two species of graptolitidæ are faintly recognized in the upper part of the black shale.

CHAPTER VI.

THE SILURIAN PERIOD.

NEXT in order, if the series of palæozoic deposits were complete in the Malvern district, should follow the great group of richly fossiliferous strata explored as Bala rocks in North Wales by Sedgwick, classed as Llandeilo and Caradoc rocks in South Wales and Salop by Murchison. The whole group is absent. There was perhaps a separation of the whole south-eastern part of the sea during the Bala period, so that no sediments of that order fell in the Malvern area: none such can be traced about Usk, Mayhill, Malvern, Abberley, or Woolhope. In these cases generally the horizon of Bala is invisible; but it is not so at Malvern. The group of rocks is not here, and the fossils, speaking freely, are absent also. No example of Asaphus Buchii, no Trinucleus ornatus, no Lingula granulata: the period is not represented by stratified deposits.

During this period, and specially in the earlier part of it, were great disturbances of the sea-bed on the west; great outpourings of fused rocks, as in the Arenig and other mountains. Nor shall we be rash in assigning to this period a part at least of the igneous rocks ejected among and above the black shales of Malvern. Let us suppose that, in connection with these operations, the Malvern area was raised for a time, and placed above the reach of that sea of the west, which was at this time so prolific in life in depths where now Aran-Fowddy and the Berwyns rise aloft in air. A general depression followed.

Then came in settled order the series of arenaceous, argillaceous, and calcareous beds, whose physical history is not materially different from other deposits of analogous composition in Silurian districts. The whole series indicates a long-continued subsidence of the sea-bed in this region; a subsidence which brought currents into the sea, most of them loaded with sandy, rarely conglomeratic sediments.

Three pauses in the 'depression' are marked by the limestones of Woolhope, Wenlock, and Aymestry. Each of these pauses was favourable to the growth of coral, and indeed large portions of the limestones are in places composed of these radiated structures.

Slaty cleavage is unknown in the whole district, though it occurs further south. There is little sign of oceanic disturbance in the whole mass of strata, which is above 3000 feet thick; but few traces occur even of strong ripple mark; and the appearances suggest a limited sea-basin, guarded from violent storms, and free from any considerable influx of fresh water. It might be about the quiet end of a sea-basin, much extended to the north and west, and there exposed to ruder wave-action and greater vertical movement. There is no reason for supposing the strata to have been deposited in very deep water.

Excepting the black shale of the Cambrian series and the purple beds which rest upon it, all the strata of Malvern are of grey, or pale-bluish colour, when examined at a considerable depth below the surface, as in the Malvern Tunnel. Near the surface these tints, indicative of protoxide or silicate of iron, become yellow or brownish, the oxide having passed to the condition of protocarbonate. The limestones have been examined as to their basis, in hope of finding foraminifera and small fragments of organic tissues, especially in the occasionally pisolitic beds of the Wenlock series. Only one foraminifer has occurred to my observation, viz. Endothyra Bowmanni, the beautiful spiral shell which I described from the mountain limestone some twenty years ago. I have seen traces of it in the Upper Silurian limestone of Russia.

In the following Table the Cambrian and Silurian strata of the Malvern region appear in their relative thicknesses:—

LOWER PALÆOZOIC ROCKS OF MALVERN, ABOVE THE METAMORPHIC SERIES, ABOUT 4660 FEET THICK.

Name of Group.	Name of Rock.	Maximum Thickness. feet.	Description.
V. Ledbury	Ledbury Shales	300	Red, grey, and purple marls, shales, and sandstones.
IV. Ludlow	Downton sandstone	100	Sandstone of different tints, with red, grey, and yellow marls.
	Upper Ludlow shale	200	Flaggy arenaceous shale, with thin shelly limestones.
	Aymestry limestone	40	Shales and concretionary limestones.
	Lower Ludlow shale	700	Grey sandy shale, with argillaceous and calcareous balls.
III. Wenlock	Wenlock limestone	280	Limestone in layers of nodules and irregular beds, with soft interposed shales.
	Wenlock shale	640	Grey sandy shale, with thin bands of limestone nodules.
	Woolhope limestone	150	Rough impure limestone, with or without sandstones.
II. Mayhill	Mayhill sandstone	500	Grey (and at the bottom purple) laminated sandstone and shales.
	Mayhill conglomerate	600	Sandstones and conglomerates of grey and purple tints.
I. Cambrian	....	50	(Interposed hornblendic trap.)
	Black shale	500	Thinly-laminated carbonaceous shale, with interposed hornblendic traps.
	Hollybush sandstone	600	Greenish, grey, or brownish sandstone.

Base of metamorphic and irruptive rocks.

If we arrange these strata in five groups, and mark in each the occurrence of remains of the classes of marine animals, we shall have the following Table:—

No.	Amorphozoa.	Actinozoa.	Echinodermata.	Annelida.	Crustacea.	Polyzoa.	Brachiopoda.	Conchifera monomyaria.	Conchifera dimyaria.	Gasteropoda.	Heteropoda.	Pteropoda.	Cephalopoda.	Fishes.
12 11 } = V.	—	—	—	—	*	—	*	—	*	*	—	—	—	*
10 9 8 } = IV.	*	*	*	*	*	*	*	*	*	*	*	*	*	*
7 6 5 } = III.	*	*	*	*	*	*	*	*	*	*	*	*	*	—
4 3 } = II.	—	—	*	*	*	—	*	*	*	*	*	—	*	—
2 1 } = I.	—	—	—	*	*	—	*	—	—	—	—	—	—	—

Here it appears very plainly that a complete system of invertebral marine life, with all the principal divisions now in existence, was fully established in the middle of the Silurian period, as it is known at Malvern; also that this system had come in gradually from a small beginning, and died out almost completely with the Ludlow rocks, the strata above being comparatively poor in life. Fishes appear only in the later deposits; no reptiles, no birds, no mammalia.

The series of lower palæozoic rocks in the Malvern region is perhaps the fullest known in so small a tract. It is not indeed quite complete. The succession of lower palæozoic rocks in Wales and the bordering counties may be represented in the following Table; the black shale and Hollybush sandstone of Malvern probably corresponding to the Tremadoc or upper Ffestiniog rocks:—

FORMATIONS OF THE LOWER PALÆOZOIC PERIOD, WITH ESTIMATES OF THEIR AVERAGE THICKNESS.

			feet.	
SILURIAN	Upper	Ledbury	250	Arenaceous. Argillaceous.
		Ludlow	1000	Arenaceous. Calcareous. Argillaceous.
		Wenlock	1250	Calcareous. Argillaceous.
		Mayhill (or Upper Llandovery)	500	Arenaceous.
	Lower	Lower Llandovery	750	Arenaceous.
		Caradoc or Upper Bala	2500	Arenaceous. Calcareous.
		Llandeilo or Lower Bala	2500	Calcareous. Argillaceous.
CAMBRIAN		Tremadoc	1500	Argillaceous.
		Ffestiniog	2500	Argillaceous.
		Menevian	2000	Argillaceous. Arenaceous.
		Harlech	2000	Argillaceous. Arenaceous.
		Longmynd	8000	Argillaceous.
			24,750	

From this it appears plainly how great a defect of sea-action must be allowed for, in treating of the lower palæozoic strata of Malvern, between the Cambrian and Upper Silurian rocks—how great a lacuna in the series of life. Again, the Cambrian strata of Malvern do not occupy in thickness more than one-tenth of that here assigned to the same groups in Wales, less than one-tenth if we adopt the thickness ascribed to them by the National Survey. It is not therefore surprising that the Cambrian fossils of Malvern are few. More may we wonder that, while agreeing generally with their contemporaries in Wales, they often differ specifically. Lastly, the upper Silurian series of Malvern, which is very complete as to the strata, is equally full in its groups of life, and those for the most part agree with contemporary associations in other parts of the old Silurian sea. Thus both differences and agreements concur in support of the geological theory in regard to the vastness of palæozoic periods, and the definite succession of life in large tracts of the sea.

In the following Tables the genera of the fossils found in the lower palæozoic strata of Malvern, including Mayhill and the Abberley Hills, are placed under their several natural classes, and the occurrence of each is marked in the five great divisions of these strata already referred to. A sixth column is added to shew how many of the genera have been found to occur again in strata of more recent date. Thus may readily be seen how large a proportion of the early generic groups has been continued through long succeeding periods. To the consideration of this subject attention will be called again.

	Hollybush.	Mayhill.	Wenlock.	Ludlow.	Ledbury.	In more recent strata.
PLANTS.						
Actinophyllum				*		
Fucoides . .	*	*				*
Pachytheca .				*	*	
Spongarium .				*		
AMORPHOZOA.						
Cnemidium .			*			
Stromatopora .			*			*
FORAMINIFERA.						
Endothyra . .			*			*
CŒLENTERATA.						
Acervularia			*			*
Alveolites . .			*	*		*
Arachnophyllum			*			*
Cœnites . . .			*			
Cyathophyllum		*	*	*		*
Cystiphyllum .			*			*
Dictyonema .	*					
Favosites . .		*	*	*		*
Graptolithus .				*		
Halysites . .		*	*	*		
Heliolites . .			*	*		*
Labechia . .			*			
Omphyma . .			*			
Petraia . . .		*				*
Strombodes .			*			*
Syringopora .			*	*		*
ECHINODERMATA.						
Actinocrinus .			*			*
Cyathocrinus .			*	*		*
Hypanthocrinus		*				
Rhodocrinus .			*			*
Palæchinus .		*				*
ANNELLIDA.						
Cornulites . .		*	*	*		
Serpulites . .	*	*	*	*		*
Tentaculites .		*	*	*		
Trachyderma .	*			*		
CRUSTACEA.						
Beyrichia . .						
Cytherina . .				*		
Cytheropsis .	*			*		
TRILOBITIDÆ.						
Acidaspis . .			*	*		
Agnostus . .	*					
Ampyx . . .		*				
Asaphus . .		*				
Calymene . .			*	*		
Cheirurus . .			*			
Cybele . . .		*	*	*		
Dalmannia . .		*	*	*		
Homalonotus .			*	*		*
Illænus . . .			*			
Lichas . . .			*			
Olenus . . .	*					
Phacops . .			*	*		*
Prœtus . . .				*		*
Pterygotus . .				*		
Sphærophthalmus . . .	*					
POLYZOA.						
Ceriopora . .			*	*		*
Discopora . .			*			*
Fenestella . .			*			*
Ptilodictya . .			*			
BRACHIOPODA.						
Discina . . .			*	*		*
Lingula . . .	*	*	*	*	*	*
Obolella . .	*					
Orbicula . .			*			*
Atrypa . . .		*	*	*		*
Chonetes . .		*	*	*		*
Leptæna . .		*	*	*		*
Orthis . . .		*	*	*		*

	Hollybush.	Mayhill.	Wenlock.	Ludlow.	Ledbury.	In more recent strata.
Pentamerus		*	*	*		*
Rhynchonella		*	*	*		*
Spirifera		*	*			*
Stricklandina		*				
Strophomena		*	*	*		*
MONOMYARIA.						
Avicula			*	*		*
Pterinea		*	*	*		*
DIMYARIA.						
Cardiola			*	*		
Cleidophorus		*	*	*		*
Ctenodonta				*		
Cucullella		*	*	*		
Goniophorus			*	*		
Mytilus			*	*		*
Orthonota			*	*		
Pleurorhynchus			*			*
GASTEROPODA.						
Acroculia			*	*		*
Cyclonema		*	*	*		
Cyrtolites			*	*		
Euomphalus		*	*	*		*
Holopella		*	*	*		
Littorina		*	*	*		*
Loxonema		*	*	*		*
Murchisonia		*	*	*		*
Natica			*	*		*
Nerita			*	*		*
Pleurotomaria		*	*	*		*
Trochus		*				*
HETEROPODA.						
Bellerophon		*	*	*		*
PTEROPODA.						
Conularia			*	*		*
Theca			*			*
CEPHALOPODA.						
Actinoceras			*			
Lituites			*	*		
Orthoceras		*	*	*		*
Phragmoceras				*		
Poterioceras		*				
FISHES.						
Onchus				*	*	*
Scaphaspis				*	*	*
Pteraspis				*	*	*

The system of life here sketched in bare outline was brought to light in 1831 and subsequent years by Sir R. I. Murchison and Professor Sedgwick, earnestly labouring in Wales and the bordering counties. It is now recognized at various points on the globe, and often fills large tracts in widely-separated regions, thus affording a general basis for a universal classification of fossiliferous strata in the order of time.

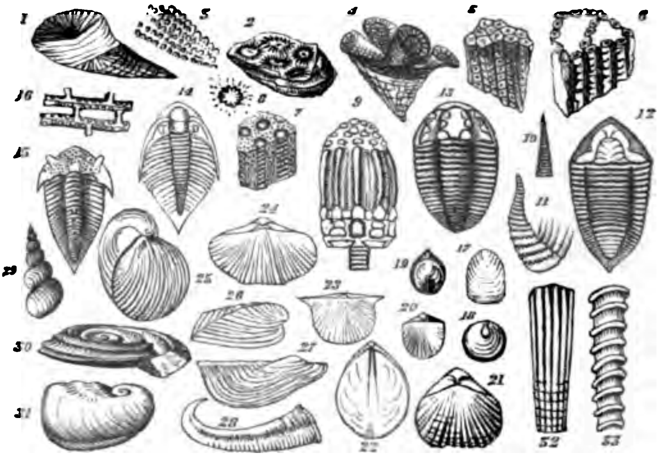

Diagram XVIII. Silurian fossils, all reduced in size.

1. Omphyma turbinata. *Linn.*
2. Arachnophyllum typus. *M'Coy.*
3 —— rays of the natural size.
4. Cyathophyllum truncatum. *Linn.*
5. Favosites gothlandica.
6. Halysites catenulata. *Linn.*
7. Heliolites interstinctus. *Wahlenberg.*
8. —— one of the cells natural size.
9. Hypanthocrinus decorus. *Phillips.*
10. Tentaculites ornatus. *Sow.*
11. Cornulites serpularius. *Schlob.*
12. Homalonotus delphinocephalus. *Green.*
13. Calymene Blumenbachii. *Brongn.*
14. Phacops caudatus. *Brongn.*
15. Encrinurus punctatus. *Brünn.*
16. Fenestella antiqua. *Linn.*
17. Lingula Lewisii. *Sow.*
18. Discina rugata. *Sow.*
19. Rhynchonella navicula. *Sow.*
20. Orthis elegantula. *Dalman.*
21. Pentamerus galeatus. *Dalman.*
22. Pentamerus oblongus. *Sow.*
23. Orthis filosa. *Sow.*
24. Spirifera plicatella. *Linn.*
25. Pentamerus Knightii. *Sow.*
26. Goniophora cymbæformis. *Sow.*
27. Pterinea retroflexa. *Wahlenberg.*
28. Ecculiomphalus lævis. *Sow.*
29. Loxonema sinuosa. *Sow.*
30. Euomphalus discors. *Sow.*
31. Acroculia haliotis. *Sow.*
32. Orthoceras canaliculatum. *Sow.*
33. Orthoceras ibex. *Sow.*

CHAPTER VII.

THE OLD RED AND CARBONIFEROUS PERIODS.

I. THE OLD RED SANDSTONE.

THE system of Silurian strata in the Malvern region was brought to an end by means of great disturbance of the levels of the earth's surface. These were not confined to the district itself, but were so extensive in their operation that their influence was felt over a great part of the circumpolar regions of the north. By their operations some oceanic basins were dried; others filled with enormous loads of fresh sediment brought from distant shores and transported in new directions; old forms of oceanic life ceased; new forms were introduced; all the physical associations were changed, yet with few or no marks of local violence.

In the Malvern district these changes are observed; they are not very sudden; the old sediments are somewhat gradually mixed, or else found to alternate with the new deposits; the old life dies out by degrees, and before it is quite exhausted some of the new forms are introduced. The sea-bed underwent no convulsion; it continued to be sinking through some thousands of feet, and was constantly receiving in comparative tranquillity layers of argillaceous, arenaceous, and partially calcareous deposits. But these were of a new order; generally of a red or pale green tint, the former colour being due to red oxide of iron, while the latter may have been caused by deoxidation of sediments originally red. This deoxidation may have been occasioned by decomposing vegetable matter; whether before the transport or after the deposition of the sediment may be matter for inquiry. Analogies for either supposition may be supplied from existing natural occurrences[a].

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[a] The discharge of colour here referred to may be seen to have happened in many flagstones of the old red series in Herefordshire and Monmouthshire, where it was well observed by Col. Sir H. James in 1842. Mr. Maw has lately investigated the subject largely.

The Old Red Sandstone is seen on the west of the Abberley and Malvern Hills, and on the west of Newent, where the new red and old red systems meet on a line of fault, prolonged from the Malverns toward Berkeley. In the wide region west of the Malverns which extends to Pembrokeshire, the series of red and pale green strata acquires a thickness of from 5000 to 8000 feet, and consists essentially of three parts[b].

Upper part. Conglomerates with thin red marls, and sandstones: e.g. the Vans of Brecon.

Middle part. Thick laminated red sandstones with thinner sandy red marls (a few greenish bands), and traces of cornstones: e.g. about Ross.

Lower parts. Thick red laminated marls and shales, variegated with greenish bands and blotches, and beds and lumps of cornstone, and including many thin beds of laminated sandstone, some of which are near the bottom. This group is the only one observable along or parallel to the ranges of Malvern and Abberley, and is about 2500 feet thick. It rests, but perhaps not quite conformably, on the subjacent Ledbury shales and Ludlow rocks.

The organic remains are few, chiefly fishes of the curious genera Cephalaspis, Pteraspis, and Scaphaspis. Very few marine shells[c]; no trilobites; no corals. Mr. Godwin Austen has expressed an opinion that the deposit is of fresh-water origin.

On comparing these two great systems of strata, remarkable contrast appears in physical characters, probable origin, and organic association.

The comparison may be in a tabular form as under:—

SILURIAN.	OLD RED.
Protoxidated sediments prevail; little or no red oxide of iron; much limestone of coral and shell growth.	Sediments rich in red oxide prevail; very little limestone, and that not coralloidal, and not shelly.
Organic remains very numerous; excepting fishes.	Organic remains scarce, excepting fishes of singular forms (e.g. Cephalaspidæ).
Sea basins opening variously to the east and north of Europe, and America, between the Ural and the Rocky mountains.	Basins (whether seas or lakes) of limited extent, mostly detached or in proximity to lately elevated land.

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[b] Memoir on Malvern, already referred to.

[c] A small species of Lingula is found in the lower beds.

Devonian group.—The old red sandstone is followed in Devonshire, and still more remarkably in the south of Ireland, by a series of shales, grits, and limestones, with a large suite of fossils, having on the whole a considerable analogy with the still richer associations of marine life in the carboniferous limestone. In North and South Devon, in the Eifel, and about the junction of the Rhine and the Lahn, these strata are thick and various. A series corresponding to them occurs in North America, but in none of these localities, except in Ireland and Devon, is there a distinct exhibition of old red sandstone. And in these districts the exhibition can hardly be termed 'normal.' Near Linton, in North Devon, and south of Plymouth we may satisfy ourselves of the fact that old red sandstone underlies the Devonian beds. In North Devon these strata of great thickness comprise one limestone of age corresponding to the Eifel rock, several grey shaly rocks full of fossils, and some purple grits and shales without fossils. Slaty cleavage affects a large portion of the lower rocks. From this series of rocks to the carboniferous strata which succeed, the transition is easy, so easy indeed that, in the opinion of Sir R. Griffith and Mr. Jukes, the whole of the Devonian series may be united with the lowest members

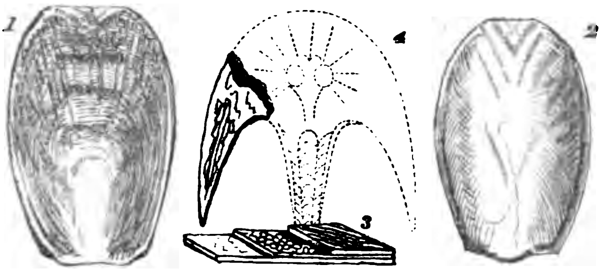

Diagram XIX.

1. Pteraspis (Scaphaspis) Lloydii. The external surface is retained. 2. Another, a cast of the interior. 3. The three plates of which the dermal covering is formed. The outer one is striated enamel; the middle one shews vertical cells of various forms; the inner one is in thin bluish scales. 4. Cephalaspis. Only one of the cornua is seen.

The specimens are from Mathon, near Malvern, in cornstone and sandstone of the old red series.

of the Irish carboniferous group (yellow sandstone and carboniferous shale). What seems ascertained truth is the close approximation in time, in character of deposition, and in forms of life, of the South Hibernian and South Welsh rocks; while the North Devonian strata contain with these a somewhat lower group, not distinctly represented in Wales or Ireland.

This period is not represented in the area of Malvern, nor, in fact, in any district to the northward; only faint indications of it can be admitted in the vicinity of the Forest of Dean, Tortworth, and Bristol. This seems to arise from no local removal of such deposits; they appear to have never reached so far northward. We may probably admit as a sufficient explanation the removal of the whole area in question from the influence of the southern or, as we may call it, the Devonian Sea, and as the best supposition to account for this, a partial re-elevation of the district.

The sequence of life is broken in the same degree as the series of strata; but a very large proportion of the Devonian fauna is continued into the cognate though later carboniferous period.

II. THE CARBONIFEROUS LIMESTONE.

The carboniferous limestone appears in a considerable mass, half surrounding the coal-field of Kingswood, in the south-west corner of the Geological Map (Plate I). It is well seen at Wickwar, where the railway tunnel penetrates the rock. It is there a grey, partially crinoidal rock, with some of the usual fossils, but not in such abundance or variety as in the prolific gorge of the Avon at Bristol. Hæmatite occurs in the fissures.

At Bristol the strata are seen highly inclined in grand cliffs; all the beds are traceable from the uppermost below what represents millstone grit to the old red sandstone. This is the whole series in general terms[d]:—

Millstone grit.

c. Alternations of limestone, reddish, grey, or dark, with shales of the same tints, and sandstones red or grey. Corals, crinoids, brachiopods, at intervals throughout the mass. 400 feet.

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[d] De la Beche in Mem. of Geol. Survey, vol. i.

b. Scar limestones; grey, reddish, mottled, brown or black; partially divided by shales; compact or oolitic, shelly, and crinoidal. 1438 feet.

a. Alternations of limestones and shales, of black, brown, or yellowish tints; the limestones usually very fossiliferous, and toward the base full of remains of fishes, cyprides, &c., constituting a fish-bed. 500 feet.

Yellow and grey sandstones below.

The presence of red oxide of iron through a great part of this series of limestones is a feature of Gloucestershire and Somersetshire, which is in some degree extended to the Forest of Dean and South Wales, but is rarely found in the same manner in the north of England. The red hæmatite of Lancashire and Cumberland is of a later date than the rock in whose hollows and fissures it is collected. Iron ore of similar quality lies in hollows and veins of the limestones of Mendip and other tracts near Bristol.

The mountain limestone and millstone grit are totally absent from the whole tract of the old red sandstone west of Mayhill, Malvern, and Abberley. Whether this entire absence is to be explained by the continued separation of the Malvernian sea from that further to the south, is not to be so confidently inferred as in the case of the Devonian rocks. For in the Forest of Dean, on the south, the limestone and millstone grit are well developed, round an insulated basin of coal strata; and it may be conjectured that as that is now insulated by denudation, other portions on the west of Malvern may have been wholly removed by that cause. On the other hand, it is observed that coal occurs on the western side of the Abberley Hills, resting on the old red, and so excluding the limestone; and a similar fact occurs in the small poor coal-field of Wire Forest on the north, and at Newent on the south of the Malvern tract. If the limestone were removed by denudation in a north and south direction, it must have happened before the æra of the coal formation.

The Table of the genera of fossils in the mountain limestone of Bristol is taken from a full and exact Catalogue of the species compiled for me by Mr. Stoddart, F.G.S., whose knowledge of that rock and of the rich geology round the city where he resides is well proved. I am not aware that such a list has been before prepared by any geologist.

Millstone grit.—A hard sandstone rock occupying the position of this grit, lies over the carboniferous limestone of Wickwar; it has not much resemblance to the millstone grit of the north of England, but is more related to the 'Farewell Rock' of the basin of South Wales. Hæmatite accompanies it.

A rock of similar character and relations is found above the great limestone series of Bristol. It is supposed to be nearly a thousand feet thick. On the borders of the Forest of Dean there is a quartzose conglomerate in the same position. On the eastern border of the Warwickshire coalfield the hard quartzose rocks of Hartshill are of the same age; they are somewhat metamorphic. I have not seen organic remains in these rocks: plants might be looked for.

The genera of vertebrate and invertebrate animals at present recognized in the mountain limestone series of Bristol appear in the following Table. The four principal divisions (including millstone grit) contain altogether a very large proportion of the fossils usually found in this group of strata. The distribution of them is also according to the usual observation elsewhere; the greatest number being found in the lower part of the limestone series, and very few in the millstone grit. Only a small number of the generic groups of the corals, crinoids, and fishes of the carboniferous limestone is found again in strata of more recent date, but many of the conchifers are repeated.

	Lower Shale.	Middle Limestone.	Upper Limestone.	Millstone Grit.	In more recent strata.
FORAMINIFERA.					
Several genera, including Rotulina, Globigerina, Textularia, &c. . . .			*		*
ZOOPHYTA.					
Alveolites . .			*		
Amplexus . .		*			
Aulophyllum .		*			
Campophyllum		*			
Chætites . .			*		
Clisiophyllum		*			
Cyathophyllum		*	*		
Lithostrotion .		*	*		
Lonsdaleia . .			*		
Lophophyllum		*			
Michelinia . .		*			
Syringopora .			*		
Zaphrentis . .		*			

	Lower Shale.	Middle Limestone.	Upper Limestone.	Millstone Grit.	In more recent strata.
ECHINODERMATA.					
CRINOIDEA.					
Actinocrinus		*			
Cyathocrinus		*			
Dichocrinus		*			
Pentremites	*				
Platycrinus	*	*			
Poteriocrinus	*	*	*		
Rhodocrinus	*				
Synbathocrinus		*			
ECHINOIDEA.					
Archæocidaris		*			
Palæchinus		*			
ANNELLIDA.					
Serpula	*				*
CRUSTACEA.					
Ceratiocaris		*			
Cythere	*				
Cytherella	*				
Leperditia	*				
Phillipsia	*		*		
POLYZOA.					
Ceriopora	*				
Fenestella	*	*	*		
Ptilopora	*		*		
Retepora	*				
BRACHIOPODA.					
Athyris	*	*			
Cyrtina				*	
Camarophoria	*				*
Chonetes	*	*			
Discina	*	*			*
Lingula	*				*
Orthis	*				
Retzia	*				
Producta		*	*	*	
Rhynchonella	*	*	*		*
Spirifera	*	*		*	*
Streptorhynchus	*	*			
Strophomena	*				
Terebratula	*	*			*
MONOMYARIA.					
Aviculopecten		*			
Pecten		*			
Pinna ?				*	
DIMYARIA.					
Cypricardia	*				*
Corbula	*				*
Edmondia		*			
Modiola	*	*			*
Myacites	*	*			*
Pleurorhynchus	*	*			
Pullastra		*			*
Sanguinolaria		*			*
Sanguinolites	*	*			
Sedgwickia		*			
Venus ?	*	*			*
PTEROPODA.					
Conularia	*	*			
GASTEROPODA.					
Acroculia	*				
Bellerophon		*			
Euomphalus	*	*			
Loxonema		*	*		
Murchisonia		*			
Natica	*	*			*
Naticopsis		*			
Platyschisma		*			
Pleurotomaria	*	*			*
CEPHALOPODA.					
Cyrtoceras		*	*		
Discites		*			
Nautilus		*	*		*
Orthoceras	*		*		
PISCES.					
Amblypterus	*				
Cladodus	*	*	*		
Cochliodus		*			
Chomatodus	*	*			
Ctenacanthus	*	*			
Deltoptychius		*			
Helodus	*	*			
Onchus		*			
Oracanthus	*	*			
Orodus		*			
Psammodus	*	*			
Tomodus		*			

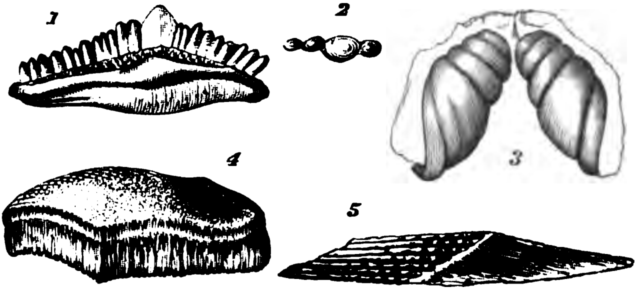

Diagram XX. 1. Tooth of Orodus cinctus (*Ag.*), seen laterally. Bristol. 2. Tooth of Helodus gibberulus (*Ag.*), looking on the crown. 3. Tooth of Cochliodus contortus (*Ag.*). The perfect Irish specimen is in the collection of the Earl of Enniskillen. 4. Tooth of Psammodus porosus (*Ag.*). Bristol. 5. Dorsal spine of Ctenacanthus. Bristol.

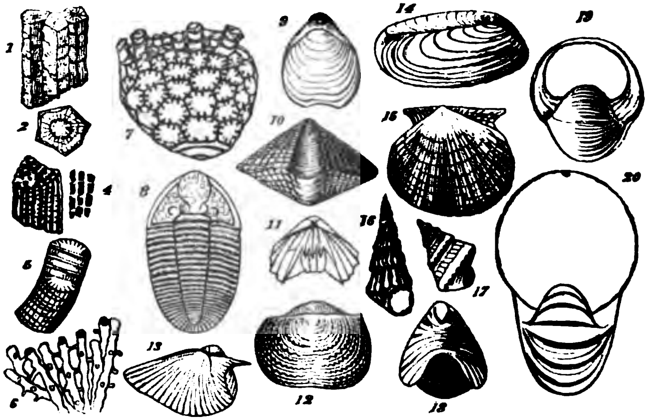

Diagram XXI. Mountain Limestone (fossils reduced).

1. Lithostrotion basaltiforme. *Phil.* 2. One of the cells. 3. Chætites septosus. *Flem.* 4. Shews the septa across the vertical tubes. 5. Amplexus Sowerbii. *Phil.* 6. Syringopora geniculata. *Phil.* 7. Actinocrinus tessellatus. *Phil.* 8. Phillipsia seminifera. *Phil.* 9. Terebratula sacculus. *Sow.* 10. Spirifera cuspidata. *Sow.* 11. Rhynchonella pleurodon. *Phil.* 12. Producta punctata. *Sow.* 13. Pleurorhynchus minax. *Phil.* 14. Sanguinolaria sulcata. *Phil.* 15. Aviculopecten granosus. *Sow.* 16. Murchisonia rugifera. *Phil.* 17. Pleurotomaria biserrata. *Phil.* 18. Acroculia vetusta. *Sow.* 19. Bellerophon apertus. *Sow.* 20. Nautilus dorsalis. *Phil.*

COAL MEASURES.

The coal measures appear near Bath, in Kingswood, at several points near Newent, in a mere line on the Abberley range of hills, and in a patch west of those hills. Some of the finest fossil plants in the Oxford Museum come from the Camerton pits in the Somersetshire coal tract; others of equal interest from the Forest of Dean. The coal band in the Abberley Hills is placed between the Permian or else new red conglomerates and the old red marl series. It is in reality conformed to neither, nor, as in the more frequent exposures of coal between the old and new red near Newent, is there any semblance of conformity to the older deposit. It is of no commercial value; nor is the value considerable of the small tract of coal, lying on old red, north of the Abberley Hills.

The occurrence of the coal with its attendant clay under these conditions, leaves no doubt of the fact that, at some time after the completion of the old red deposits, a great change took place in the sea-bed; great disturbances elevated and bent the Silurian and old red strata; and long watery action levelled the outcropping edges of these strata. On such worn surfaces the coal was deposited; the vegetable masses, to judge from their irregularity, were probably drifted, but not drifted far, or into deep water. No plants of interest have been collected from it. There was extensive land near, if not on the very range of the Malvern and Abberley Hills, and further north, toward Wire Forest and Shrewsbury, and further south, toward Newent and Kingswood. Thus we have evidence of another disturbance, accompanied by elevation of the old sea-bed of the Malvern area, at least in part, above the level of the sea.

These small patches of aggregated plants converted to coal, which lie on the old red sandstone, are they to be regarded as mere ruins of a larger deposit once collected in a great tract, chiefly on the western side of the axis of the Malvern movements, though now broken piecemeal by subsequent denudation? If so, the denudation happened probably before the Permian and new red sandstone period. In favour of this view, it may be said that there is some ground for regarding all the detached patches as belonging to the same geological horizon as the poor coal-beds of Wire Forest, and these represent the lower part of the richer coal-field of the Severn.

Or do they appear now nearly as they were deposited, under conditions unfavourable to the full development of the coal strata, either because of the situation being uncongenial to the growth or unsuited to the conservation of the plants which compose the basis of carbonaceous deposits?

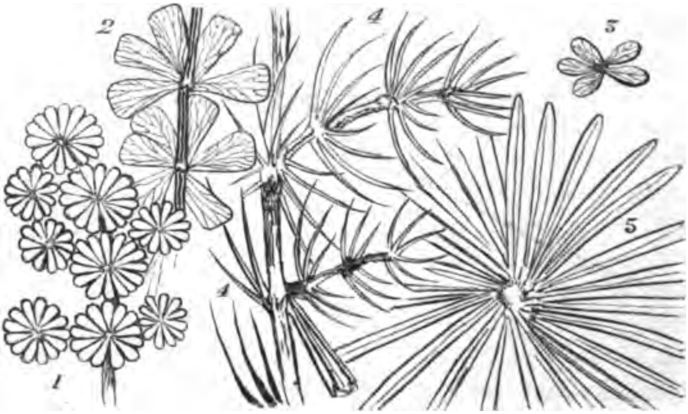

Diagram XXII. 1. Annularia brevifolia. *Brong.* Forest of Dean. 2. Sphenophyllum Schlotheimii. *Brong.* Forest of Dean. 3. Sphenophyllum ovale, natural size. *Phill.* Forest of Dean. 4. Hippurites longifolius. *Lind.* Forest of Dean. 5. Asterophyllites (Annularia) equisetiformis. *Brong.* Forest of Dean.

To whichever of these views he may be inclined, the geologist, standing on the line of the hills anywhere between Abberley and Newent, and looking eastward over the broad areas of later stratifications, must feel strongly moved to consider the theoretical question of the possible or probable extension of rich coal deposits on the eastern side of the Malvern and Abberley Hills; he must be forced to consider the practical question of what may be the depth to be reached by shaft or pit on reasonable computation, before that coal can be attained; and it may be that before this century be ended some such trial must be made. Before adopting any decided opinion on either of the questions, we must examine into the history of the strata which lie on the eastern side of the Malvern Hills, between them and Oxford.

The organic remains of the coal districts of Abberley, Newent, and Kingswood are little known. Those of the Forest of Dean and the Somersetshire coalfields are very numerous and of great beauty and interest. The Oxford Museum contains a considerable number.

In the following Table the genera of coal plants found in the districts named are ranged according to their probable affinities; the Somersetshire and Gloucestershire localities being in separate columns:—

	Somersetshire.	Gloucestershire.
Filices.		
Alethopteris	*	*
Caulopteris	*	
Neuropteris	*	*
Pecopteris	*	*
Filicites	*	
Lycopodiaceæ.		
Aspidiaria	*	*
Halonia	*	
Lepidodendron	*	*
Lepidophyllum	*	*
Ulodendron	*	
Equisetaceæ.		
Annularia	*	*
Asterophyllites	*	*
Calamites	*	*
Hippurites	*	*
Sphenophyllum	*	*
Sigillariaceæ.		
Carpolithus	*	
Dadoxylon	*	
Sigillaria	*	*
Trigonocarpon	*	

CHAPTER VIII.

THE POIKILITIC PERIOD.

PERMIAN, TRIASSIC, AND RHÆTIC DEPOSITS.

WE now enter on a very different series of rocks, accumulated under new conditions, on the eastern side of the great palæozoic region of Malvern and Wales. For this series the term Poikilitic has been at different times employed by myself; but of late years, not on account of mineral distinctions, or of different physical origin, the lower portion has been separated under the title of Permian, imposed by Sir R. Murchison on a great development of it which he explored in Russia. Some time previously I had proposed the separation, on the *ground of the fossil contents*, of the magnesian limestone series of England from the new red series, to which by *mineral affinities* and physical origin it is naturally allied, and had united it with the carboniferous system, to constitute an upper palæozoic period. Both of these views have been adopted—the Permian system as defined by Murchison[a], and the relation of its fauna to that of the carboniferous system as announced by myself[b].

In some respects and in some districts it is, however, more convenient to adhere to the old established alliance of the Permian many-coloured deposits, with the variegated sandstones and clays of the new red series; for the *physical history* of these two great groups is on the whole one great sequence of natural operations. There are indeed cases, as in Lancashire and Cheshire, and in a less degree in Derbyshire, where a kind of gradation appears between the coal formation and the Permian sandstones which are locally conformed to it; so that, in fact, we shall do wisely to adapt our classification to the region which specially engages attention, for local description and limited inference. In the case now in hand there can be no hesitation in choosing to treat of the whole series between the coal and the rhætic base of the lias as one great physical 'Poikilitic' series; the method followed in all my works till the year 1840.

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[a] Memoirs on the Geology of Russia, by Sir R. I. Murchison, M. de Verneuil, and Count Keyserling, in Geol. Soc. Proceedings, 1842, 1843, &c.

[b] Penny Cyclopædia, article 'Saliferous System;' also Palæozoic Fossils of Devon and Cornwall, 1841, p. 160. Conybeare employed the term Pœcilitic.

I propose to describe the products of this period in two geographical sections; the first connected with the Vale of the Severn, the other with the Warwickshire Avon, these being much different in some respects.

THE PERMIAN SERIES

comes nowhere into the drainage of the Thames, and is hardly found anywhere within the range of country represented on the map (Plate I. in this volume), except in a narrow band of brecciated or conglomerate rocks which cling to the east face of the Malvern Hills, and form separate summits on the Abberley range. To this peculiar rock I gave the title of Haffield Conglomerate[c], from a point south of Malvern where it is very conspicuous. I treated it as the lowest part of the new red sandstone. It is now generally regarded as a part of the Permian series of rocks. It is about 200 feet thick.

Along the southern end of the Silurian tract, west of the Malvern chain, this conglomerate extends, in a narrow band abutting unconformably against those rocks, which had undergone enormous waste before it was accumulated. It is a mass of fragments more or less rolled and cemented by fine red sedimentary matter. The fragments are such as the neighbouring hills might supply. They are often polished, almost as if glazed on the surface. It is but slightly traceable along the eastern face of the hills till we pass the northern end, when it reappears about Alfrick and Rosemary rock. Along the Abberley Hills it is seen in Berrow Hill, Woodbury Hill, and about the Hundred House, and at points farther north. In this district it contains rock fragments which cannot be derived from Malvern or any neighbouring hills. They may perhaps have come from the country near Shrewsbury, along the line of ancient coast, by drifting. Professor Ramsay invokes the help of floating ice. No fossils occur in this curious rock.

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[c] Memoirs of the Geological Survey, vol. ii. pt. 1.

The heights reached by the Permian conglomerates are very moderate near Malvern, but grow considerable as we proceed northward. At Haffield, south of the Malvern range, 400 feet; Rosemary Hill, north of it, 340 feet; Berrow Hill, further north, 630 feet; Woodbury Hill, 930 feet; highest point of Abberley Hills, 940 feet. This rising of the conglomerate hills to greater heights as we go northward is the more remarkable, as the older strata on which or against which they rest are found to be less and less elevated in that direction. The Permian beds never pass over the summit of the anticlinal curvatures in the Silurian beds of the Abberley range.

Above the Haffield or Permian conglomerates we have, in the Malvern district, red sandstones of considerable thickness, and on these white sandstones. They are but slightly exposed, however, in contact with the Malvern rocks, and then appear in a very confused state. Much more complete in all respects is the series of these strata about Newent, where red sandstone and conglomerate, 200 to 400 feet thick, divided by red shales and capped by white sandstones, are very extensively seen. The pebbles of the conglomerate are mostly of quartz. Similar observations may be made on the eastern side of the Abberley Hills, about Martley. No organic remains have been found in these strata, the upper part of which corresponds apparently to the sandstone of Grinshill, near Shrewsbury, which yields the curious fossil reptile named Rhynchosaurus.

Then follows, in the Malvern region, the thick deposit of red marls, 400 to 500 feet, which indeed have in their lower part some white and red sandstone bands, thereby obscuring the limit of two deposits, which are strongly enough contrasted on the whole. Still higher in the midst of the marls occur some other thin sandy layers, and, after another interval, somewhat thicker and more varied sandstones and shales of a pale blue colour, which constitute the Keüper sandstone and contain fossils, about twenty feet thick at the most. These are well seen about Pendock Rectory, south-east of Malvern, the residence of an active explorer of these beds. Remains of fishes and reptiles, with a few shells and land plants, occur in these strata, with many small fragments of various stones, jasper, quartz, coal. It is in some sense an earlier bone-bed—a precursor of the rhætic deposits.

And, to complete the deposit, we have next above 200 or 250 feet of red marls, with pale grey or greenish bands; these latter more abundant toward the upper part, and in fact constituting without any red portion the uppermost layer, often twelve feet thick. In a few places gypsum shews itself among these red marls, above the Keüper, but not abundantly; and common salt exists in them farther north—about Droitwich—as indicated by the brine springs.

Thus, on the whole, the Poikilitic series on the east of the Malvern range consists of—

	feet.
Upper red and pale green marls	250
Keüper sandstone and shale	20
Lower red marls	500
Red and white sandstones and conglomerate	400
Haffield conglomerate	200

all the thicknesses being taken at the maximum.

The Poikilitic strata, in their differences, in their inclination, relative position, and order of succession, are exactly as might have been expected to occur in a sea opened to new sediments which washed the exposed and wasting cliffs of the ridge of Malvern rock. If we could now restore the sea to the height of 600 feet above its actual level, and let its currents rake the Malvern Hills, for a long succession of ages, there would be formed in the actual Vale of Severn a pleistocene series of gravels, sands, and mud, in the place of the conglomerates, sandstones, and marls which we have been considering. By 'working up' again the red deposits, which would form the bed of this sea, there would be really a *newer red series*, of pleistocene age, quite comparable, except in magnitude, to the great mass of earlier deposits.

Just such an operation happened at the beginning, and was continued through a part of the Poikilitic period.

A great disturbance of the Malvern district, and of tracts very much extended beyond it, preceded this class of deposits. In consequence of this, the whole line of palæozoic rocks from the country near Newent to Shrewsbury was displaced and disturbed; the Malvern chain fronted a sea, perhaps a new sea, of waters on the east: in these waters the red and white sandstones and conglomerates and marls which compose the Triassic or Poikilitic system were deposited. All was sea to the east; a large tract of land existed to the west. The cause of this was a great fault on the eastern face of the Malvern Hills, which depressed all the country to the east.

Geologists have gradually allowed themselves to be convinced of the great truth, that the exterior parts of the earth have everywhere been subjected to rising and falling; rising in one district, sinking in another; almost every tract covered by the sea for a long period, and then lifted above the general level to constitute land, suffer degradation by rain, and give origin to rivers.

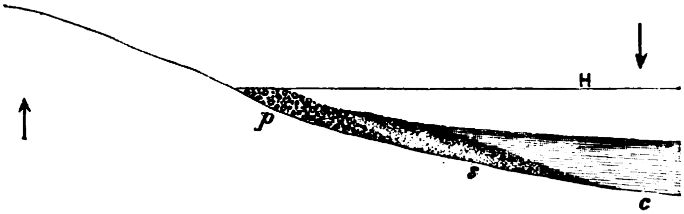

Diagram XXIII. Sedimentary shore deposits.

In the diagram above sketched, H may represent the sea-level, above which, on the left, the land may be rising, as marked by the upward arrow, and on the right the sea may be regarded as sinking. In this case the land would be coming under conditions of increasing waste, and the sea of acquiring fresh deposits on its bed. These deposits would consist, usually, of pebbles, sand, and clay; and these three sorts of materials would be found not parallel, but in something like the way represented in the diagram, where *p* is a beach of pebbles lying in much inclined though irregular layers against the shore; *s* a bank of sands drifted further; and *c* the clay carried quite away from the shore, so as to slowly settle in nearly parallel and generally almost horizontal sheets.

In a general point of view, neither the depression of a tract so as to become sea, nor the elevation of a tract so as to become land, was sudden, though there may be exceptional cases. These great mechanical effects were the result of continued pressures on materials always in some degree flexible, for no rocks are absolutely incapable of yielding to force. These pressures were for the most part exerted in very wide areas of work, during periods of long duration. In the course of these periods, and in some districts, the accumulated strain was relieved, and the flexures of the strata were changed into fractures. We term these interruptions of continuity 'faults,' and they are justly regarded as mechanical effects produced in a short time, or even suddenly, as by a sharply cut fissure, on one side of which the strata were elevated, on the other side depressed.

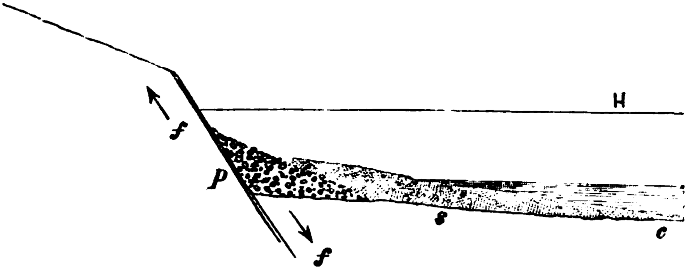

Diagram XXIV. Deposits against a fault.

In the above diagram the plane of a fault, by which pressure was relieved, is marked by *f*, and displacement is conceived to have occurred on the face of a sea-cliff, H being the sea-level, as before.

The deposits of pebbles, sand, and clay will in this case be nearly as in the former example; except that against a high cliff, with deep water, the rocky fragments will have more of a brecciated character, and be accumulated to a greater thickness. Thus may be understood the thick magnesian conglomerates and breccias, at the foot of the great Ingleborough fault; and the equally thick Permian accumulations of like nature and nearly equal antiquity along the eastern side of the Malvern and Abberley Hills. In each case the fragments are mainly, if not wholly, derived from the hills on the line of the fault, though not necessarily from the immediately opposite fronts of the hills.

The preceding observations apply to the filling up of a submarine area, or sea-bed, and to a given period of time. If we conceive the process to go on, so that at last the whole basin may be filled, or nearly so, and filled under the influence of storms and calms and tidal ebb and flow, the results may be modified. The water forces being greater at intervals, will then distribute the gravels and sands to greater distances from the shore: the several kinds of matter may be somewhat mixed, and there may be alternations of them. There may be sandy conglomerates, and argillaceous sands; and there may be alternations of these, especially in the upper parts, where, by reason of the shallowing of the water, the force of the waves and currents becomes sensible on the sea-bed far off from the land. Thus gravels and sands are accumulated in patches, and form banks, and clay settles in the least disturbed and relatively deepest parts of the sea. The clay beds always retain the character of greater continuity and more uniform thickness, and greater distance from shore.

In a continuous system of sedimentary deposits there may be zones of mineral distinction among the sediments not parallel to the horizon, interspersed patches of coarser ingredients, and connected sheets of argillaceous ingredients. These latter are often the best marks of contemporaneity.

The Poikilitic series appears all round the liassic border of the Thames basin, but never enters it. An interesting development is known in the district of Coventry and Warwick, where, with some difficulty and not without hesitation, the three elements of Permian, Bunter, and Keüper have been recognized, the two first being very near of kin. The series stands thus, much as at Malvern:—

Red marls.
Upper (Keüper) sandstone and marls.
Lower red marls.
Lower (Bunter) sandstone.
Permian beds.

This series is fossiliferous; reptilian remains and shells being not indeed plentiful, but yet found at several places, from whence they have been collected by Dr. Lloyd, the Rev. P. B. Brodie, and other geologists, and placed in the Warwick Museum.

To the Permian period are referred some considerable tracts of red sandstones and red clays and shales, which lie over the coal strata of Warwickshire, as about Coventry, at Meriden and Arden. These were till lately classed with the new red strata, and regarded as the lower part of that system, called by German geologists the 'Bunter Sandstein.' They are conjectured to be 2000 feet thick. In connexion with these, some partially calcareous beds occur at Exhall, and yield shells of the genus Strophalosia, which is found in the magnesian limestone of Durham, and is allied to the well-known Productæ of the mountain limestone. In the neighbourhood of Kenilworth and Coventry portions of the head, jaw, and teeth of a labyrinthodont reptile (Dasyceps Bucklandi) have been found, with cycadiform plants; and coniferous wood at Allesley. Lepidodendron and calamites are quoted from Exhall. At Kenilworth, in sandstone conglomerate, some corals, encrinite stems, and shells of Permian type occur [d].

The whole catalogue of organic remains from the Warwickshire Permian beds stands thus:—

Plants.	Caulerpites oblonga. Meriden.
	„ triangularis. Meriden.
	Breea eulassioïdes. *Lloyd.* Meriden.
	Coniferous wood. Allesley.
	Lepidodendron dilatatum. Exhall.
	Sternbergia. Exhall.
	Calamites. Exhall.
	Unascertained. Meriden.
Corals.	.... Kenilworth.
Crinoids.	(stems) Kenilworth.
Brachiopod.	(Strophalosia?). Exhall.
Reptiles.	Dasyceps Bucklandi. Kenilworth, Coventry.

On this catalogue a few remarks may be useful. The plants here named, Caulerpites oblonga and C. triangularis, are found in the reddish building sandstone of Meriden, near Coventry. As usual in such cases, the substance of the plant is removed, and its natural affinity can only be determined, or conjectured, by examining the form of the impression and the markings of the surface. Caulerpites, supposed to be a genus of fossil marine plants, has left one species (C. selaginoïdes, *Sternberg*) in the marl slate of Durham.

Of Breea eulassioïdes no description has yet been published.

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[d] Howell, Memoirs of Geological Survey—Warwickshire Coalfield. 1859.

The silicified wood found at Allesley belonged to large trees (coniferæ), and was described by Dr. Buckland, in a paper read to the Geological Society, in 1836.

The specimens referred to Lepidodendron, Sternbergia, and Calamites, found in sandstone at Exhall, may be regarded as confirming the general analogy of the Permian fossils with those of the carboniferous system, and the same conclusion is supported by the Strophalosia, a genus allied to Producta, found at Exhall, and the corals and crinoids, as far as they have been determined, found at Kenilworth.

The remarkable cranium of a fossil reptile, formerly described by Dr. Lloyd as Labyrinthodon Bucklandi[e], appears, by later examination of Professor Huxley, to require separation from the rather unsettled generic group to which it was referred. He has named it (from the roughness of the surface) Dasyceps Bucklandi[f]. The cranium, between the extremities, is 10 inches long, and 9½ broad. Diagram XXV. fig. 1, taken from Professor Huxley, shews the small round orbits placed far back, and between them the parietal foramen; in front the small round nostrils are seen widely separated, and between them the long oval facial fontanelle, bounded by the pre-maxillary, nasal, and anterior frontal bones. The sutures are to a considerable extent traceable, though the fossil is not in a favourable state for minute scrutiny. The quadrate bones at the base of the isosceles triangle formed by the cranium shew how broad was the opening of the jaws. The occipital bone projected retrally in two remarkable ridges, which were supposed, at first, to be the double condyles of a labyrinthodont. The real condyles have not, it appears, been discovered. Teeth slender, curved, striated.

The country about Warwick and Leamington and Coventry shews the same series of red beds as that near Worcester, not excepting the Keüper. In addition, the sandstones are more fully exhibited, and yield more numerous and more characteristic remains of large reptiles; Labyrinthodon and Cladyodon, among others frequent in the country near Warwick, are well exhibited in the museum of that town.

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[e] British Association Report for 1849, p. 56.

[f] *Δασύς*, rough. Memoirs of Geological Survey—Warwickshire. 1859. Two figures.

With this group of rocks we take leave of the peroxidated sediments. Above the gypseous marls there are in our district no more of the richly red sandstones or marls, and we lose the peculiar reptiles of that age; but, in return, we gain a new series of life, far more varied and not less interesting, brought into this part of the ancient sea with sediments of another order, derived from some other region. No convulsion here, no mark of any the least disturbance, except of sea-level, accompanies the great change. It is not a very limited change, for it affects all the north of Europe; Britain, France, and Germany equally bear witness to the extent and importance of the physical agencies which accompanied the transition from the Poikilitic period to the epoch of the Lias.

ORGANIC REMAINS IN THE NEW RED STRATA OF THE WARWICKSHIRE DISTRICT.

	Bunter.	Keuper.
PLANTS.		
Calamites	....	Shrewley.
Walchia hypnoides. *Brongn.*	....	Shrewley.
Echinostachys oblongus. *Brongn.*	....	Shrewley.
Voltzia	....	Shrewley.
Calyx of unknown plant	....	Shrewley.
Fruit of unknown plant	....	Leicester.
CRUSTACEA.		
Estheria minuta. *Goldf.*	....	Shrewley.
FISHES.		
Dipteronotus cyphus. *Agas.*	Bromsgrove.	Gloucestershire.
Palæoniscus superstes. *Agas.*	....	Shrewley.
Lophodus, palatal tooth, spine	....	Shrewley.
Sphenonchus hamatus. *O. G. S.*	High House, Warwick.	....
Acrodus minimus. *Agas.*	High House, Warwick.	Shrewley.
Skin of shark	....	Shrewley.
REPTILES.		
Labyrinthodon pachygnathus. *Owen*	Coton-End, Cubbington.	....
„ leptognathus. *Owen*	Coton-End, Cubbington.	Shrewley.
„ salamandroides. *Owen*	Guy's Cliff.	....
„ ventricosus. *Owen*	Coton-End.	....
(Anisopsis) scutulatus	Leamington.	....
Cladyodon Lloydii	Coton-End, Leamington.	....
Rhynchosaurus, footprints	....	....
Cheirotherium, footprints	....	....
Hyperodapedon Gordoni. *Huxley*	....	....

Palæosaurus,
Teratosaurus,
Thecodontosaurus, } have been determined by Professor Huxley in the Warwickshire Trias.

For the above list I am indebted chiefly to the Rev. P. B. Brodie. The specimens are mostly in the Warwick Museum.

Several of these fossils occur at Pendock and other localities where the pale tinted Keüper sandstones expand near the Malvern Hills. With these lies Pullastra arenicola.

Of the plants here mentioned as found in Keüper sandstone little is to be remarked, but they are interesting as being among the rarest of British fossils, a distinction which further research in the Midland counties is likely to remove.

Estheria minuta, which accompanies them, occurs in the Rhætic beds above.

The fishes present a remarkable concurrence of an old genus, Palæoniscus, with the ordinary Cestraciont teeth of the new red period.

The reptiles, mostly referred to Labyrinthodonts, have not as yet furnished complete means of determination, so that the species, as suggested by Owen, must be regarded as in some degree provisional. It seems doubtful whether the original Mastodontosaurus Jägeri is to be counted among them (the specimens are supposed to be lost), but it is represented by an animal quite as gigantic, the head being conjectured to be two feet in length.

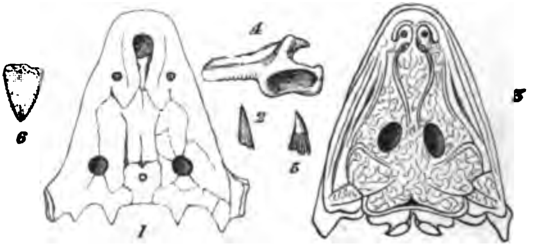

Diagram XXV. 1. Cranium of Dasyceps Bucklandi (*Lloyd*), from the Permian sandstone of Kenilworth. 2. Tooth of Dasyceps Bucklandi. 3. Cranium of Labyrinthodon Jägeri, from the Wirtemburg fossil. The species is supposed to be one of those found in the Bunter sandstone of Guy's Cliff, near Warwick. 4. Ilium of Labyrinthodon pachygnathus (*Owen*), from Cubbington, in Bunter sandstone. 5. Tooth of the same. 6. Tooth of Palæosaurus platyodon (*Riley*), from Redland, near Bristol.

Cladyodon Lloydii, known only by its tooth, which is compressed, seems to be of Dinosaurian affinity.

Perhaps the most remarkable among the reptiles is Hyperodapedon Gordoni, originally determined by Professor Huxley, from specimens found in the red sandstones near Elgin.

At the close of the Poikilitic æra we may indulge in a brief retrospect of some of the physical conditions which the successive deposits reveal to us in the sea and on the land. Taking the most general view of the mineral characters of the rocks, and including for this purpose the uppermost or rhætic beds, we find, in respect of the tints and associated phænomena, several remarkable stages and repetitions. First in regard to the sea:—

BLUE or DARK.—Rhætic beds, rich in organic remains.

RED.—New red and Permian formations of sandstones and shales, with little of limestone, and few fossils. [Elsewhere magnesian limestone is not rare in the Permian, and shelly limestone (muschelkalk) occurs in the new red.]

GREY.—Carboniferous limestone formations, rich in various oceanic life. [Towards the borders of the sea and in estuaries sandstones, shales, ironstone, and coal.]

PURPLE and GREY.—Devonian formations; purple and grey sandstones and shales, and limestone; the grey strata fossiliferous.

RED.—Old red sandstone; great mass of sandstones and conglomerates, with small and peculiar bands of limestone, containing fishes; fossils on the whole not plentiful.

GREY.—Silurian strata, composed of limestone, sandstone, and shale; nearly in all parts richly fossiliferous.

GREY and PURPLE.—Cambrian strata, containing but little of limestone, but much dark and grey shale; toward the lower part purple beds; the series yields in particular dark and grey zones abundance of trilobites.

These various purple, grey, and red sediments indicate the waste of different shores and surfaces of land. The sea received at successive times the spoils of different lands by currents arriving in different directions. There was first a pre-Cambrian land, which yielded one set of materials; next a pre-Silurian land, whose mineral constitution was not the same. Then Silurian land appeared, followed by Devonian and Carboniferous land.

Twice in this flow of time came the red deposits which may be called exceptional, and whose origin is not explored. We may indeed suppose the sesquioxide of the Poikilitic series to have been derived from the red hæmatites of the carboniferous limestone [this hæmatite is often of Permian age], or, as has been sometimes conjectured, from the old red rocks; but in each of these cases remains the question, 'Whence came *originally* the red oxide?' Perhaps, we may answer, from decomposed minerals of volcanic or metamorphic origin; silicated peroxides altered in an immensity of time by the slow action of the elements. In this point of view

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it is worth calling to mind that enormous physical changes—great displacements of land and sea—preceded in each case the deposition of the only two extensive and abundant stratified deposits of red oxide of iron known in Europe. One later case occurs, indeed, at the base of the chalk of Yorkshire, Lincolnshire, and Norfolk, and for that a similar supposition has been proposed.

To complete the retrospect, we have only to call attention to the well-established fact of the paucity of fossils in the purely red beds; their comparative rarity, or even total absence, in the purple beds; and their abundance (even contemporaneous abundance) in the grey beds. Was marine life very rare in the directions from which the red streams flowed? Was the fine red mud hostile to the growth of mollusks and corals, by impeding the action of the respiratory organs? Or, finally, were the sediments brought down by great rivers like the Mississippi and its branches, and so necessarily almost devoid of oceanic life? We may adopt such a conjecture as the last with no great hesitation, and it agrees in some degree with the ingenious supposition of Mr. Godwin Austen, without requiring, as he does, that the sediments should have been deposited in a lake of fresh water.

CHAPTER IX.

THE RHÆTIC PERIOD.

PERHAPS no part of the series of English strata gives clearer proofs of the progress of critical knowledge, or encourages stronger expectations of additional discoveries by continued observation in new localities, than the horizon which we have now reached. Formerly the line of division between the new red marls and the liassic deposits was drawn with entire confidence: a mere glance at the unproductive red marls and sandstones was enough to send many geologists away from them to the more congenial blue clays and limestones full of fossils, which had the aspect of a new creation of life. The first geologist to express an opinion that the so-called liassic beds contained in their lowest part fossils of an earlier type—that they were, in fact, triassic as far as the fishes and reptiles were concerned, was Sir Philip Egerton. His observations applied specially to the rich bone-bed of Aust, which yields, among other well-determined fishes, Acrodus, Ceratodus, Gyrolepis, Hybodus, Nemacanthus, and Saurichthys, the species being on the whole of a triassic rather than liassic type; and, among reptiles, Plesiosaurus and Ichthyosaurus.

Important as these observations were, they would hardly have occasioned the introduction of a new term for a new group of strata intermediate between the new red and the lias; but they were strengthened by discoveries in the Tyrolese and Swiss Alps, where deposits were found at Hallstadt, St. Cassian, and Kössen, which yielded abundance of fossils, and among them ammonites of peculiar character, the whole appearing to represent a fauna intermediate between the trias and the lias, as previously known. Thus evidence was presented on a large scale of a long period, previously only conjectured, with a great series of ascertained inhabitants of the sea previously unknown. To the upper part of this series, the Kössen group, the term Rhætic or Upper Trias is now commonly applied; and it is generally admitted that some at least of the lowest English and Irish beds of what was formerly called lias must be put in the same class.

The Rhætic strata preserve a nearly uniform thickness over considerable spaces, and are perfectly conformable to the poikilitic series below, and to the liassic series above. In regard to their many thin parallel strata, and the state of the iron oxide, and the abundance of iron sulphide, they resemble the lias, and may be regarded as brought into the sea of the period by currents different from those which supplied the red sediments, and dependent on distant earth movements. They appear to have been deposited in shallow water, liable to dryness, and possibly to the occurrence of brackish if not fresh water, as in the case of the Estheria bed, which contains plant remains of a group resembling fresh-water Naiadaceæ.

Though not seen in the drainage of the Thames, these interesting strata—intermediate in position between the poikilitic and the liassic deposits—occur in the Vale of Severn, and in the country near Stratford-on-Avon. They may be well and conveniently examined in Garden Cliff, at Westbury-on-Severn. Several descriptions by excellent observers have been published of this admirable natural section. The following, prepared after repeated examination by Mr. J. E. Lee and myself, differs little from those given by Dr. Wright and Mr. Etheridge[a]:—

Strata.	ft.	in.	Fossils.
LIASSIC			
Thin limestone	0	2	Ostrea liassica.
Clay	2	0	
Thin limestone (two floors)	0	6	Monotis, Modiola.
Insect limestone (Brodie)			Myacites, Insects.
RHÆTIC.			
Grey shale and thin skerry laminæ	9	0	
White and grey limestone, lumpy and laminated Clay and thin limestone below	0	9	Estheria: Naiadites.

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[a] Memoirs of Pal. Soc., 1862, pp. 69, 70.

Strata.	ft.	in.	Fossils.
Lumpy grey shale	5	0	Pullastra, Pecten.
Dark shale	4	0	
Arenaceous shelly band	0	1	Pullastra, Cardium.
Shale	2	3	
Bone grit	0	0½	Pullastra.
Dark shale	3	9	Pullastra, Tooth.
Dark thinly-laminated shale . .	1	4	(No fossils.)
Dark shale	2	3	Pecten Valoniensis.
Pyritous *Bone grit*	0	1	Acrodus, Saurichthys, &c.
Dark shale	1	5	Saurichthys and other fishes.
Bone grit, ripple marked	1	0	Bones frequent.
Dark shale	2	3	Fucoids.
Skerry laminæ, *bones*	0	3	Pecten, Pullastra, Bones.
Dark shale	1	4	
Total thickness of Rhætic beds	34	6½	
Poikilitic.			
Grey marls	18	0	
Red and grey marls	30	0	

The appearances are not quite the same, and the measures are somewhat unequal in different parts of the cliff.

In this section it will be observed that the uppermost thin layers of limestone are left to the liassic series, the rhætic ending with the higher Pullastra shale. This is not the classification adopted by the Geological Survey, which includes the Monotis bed in the rhætic group. There are reasons for each of these methods. On the supposition that the whole group is to be treated as to some extent independent both of trias and lias, as Mr. C. Moore's remarkable discoveries[b] in Somersetshire seem to require, it will be often useful to include with the rhætics the lowest members of true lias. But, if we wish to mark by a strong line the distinction of the two groups, it will be convenient to give, as Dr. Wright does, and as Mr. Brodie approves, the Monotis, or Insect or Guinea bed, to the lias. It is, in fact, the lower or 'bone-bed' series, with Pullastra arenicola, which manifests the principal affinity with the triassic deposits.

The calcareous band at the base of the Estheria bed, sometimes constituting a great part of that bed, is much alike in some respects to the so-called landscape stone of Cotham, near Bristol, and is probably its representative. That stone has usually been regarded as the base of the true lias.

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[b] On Rhætic Beds and Fossils. Quar. Journ. Geol. Soc. vol. xvii. p. 483.

The section of contemporaneous beds at Wainlode Cliff, near Tewkesbury, was examined by Mr. Strickland[c], and Mr. Brodie[d] has given a statement of the insect and other organic remains found there. The series may be thus epitomized, drawing the line for the base of the lias as before stated :—

Strata.	ft.	in.	Fossils.
LIASSIC.			
Black clay	3	0	Oyster beds.
Limestone, hard, blue, with Ostrea and Modiola minima	0	4	
Shale, yellow; traces of fucoids	0	10	Monotis bed.
Limestone, grey and blue, with insects	0	5	
RHÆTIC.			
Marly clay	5	3	
Limestone, hard, yellow, nodular, with Estheriæ, Cyprideæ, Unio, plants, and fish-scales	0	7	Estheria bed.
Yellow clay	9	0	
Black shale	3	0	
Grey stone, with fucoidal impressions above, and scales and teeth of fishes	0	1	Bone bed.
Black slaty clay	1	6	
Pyritous stone containing Pecten and other shells	0	4	
Black shale	8	0	
Bone bed, hard pyritous stone, with bones, scales, and teeth of fishes. Thin sandstone, with Pullastra	0	3	Bone bed.
Black shale	2	0	
Total thickness of rhætic beds	30	0	
POIKILITIC.			
Green and red marls occur below.			

One other section may be given, that which Messrs. Graves and Kershaw obtained by sinking through the strata at the base of their lias quarry at Wilmcote, near Stratford-on-Avon[e].

The beds here counted by Dr. Wright as of the Westbury group, begin with the Estheria bed, and fit the classification already given; a small addition is made of the thin clay and layer above it.

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[c] Geol. Proc. iii. p. 586 ; iv. p. 16.

[d] Fossil Insects, p. 58.

[e] Dr. Wright has recorded the result of this interesting experiment, Geol. Soc. Journal, 1860.

Strata.	ft.	in.	Fossils.
Liassic.			
Hard dark shale	1	0	
Shelly limestone	0	1	Insects.
Rhætics.			
Green clunchy shale	3	0	
Greenish marl (Estheria bed) . .	0	3	Estheria minuta.
Blackish shale, not laminated . .	12	6	
Greenish black laminated shale .	1	0	
Closely laminated shale	0	6	
Shale laminated (Upper Pullastra bed)	1	6	Avicula contorta, Pullastra arenicola, Cardium.
Hard shale, not laminated . . .	2	6	
Dark clay and shale	0	6	
Strong laminated clay, with Septaria	1	3	
Clay with shells (Pecten bed) . .	1	8	Pecten Valoniensis.
Black, hard, laminated clay . .	4	0	
Pyritic stone with shells (Lower Pullastra bed)	0	1	
Black clunchy clay	0	8	
Soft light brown clay . . .			
Total thickness observed	29	5	

The organic remains of these rhætic beds, the lowest of the liassic series, as understood by Smith, Conybeare, and Buckland, are not numerous in this part of England. It is likely, however, that the following short catalogue will be increased by further research. The Insect or Monotis bed is not included, for reasons already given, and the fossils of Aust are omitted :—

Plants.

Naiadæ. Some parallel-veined endogenous leaves in the Estheria bed are referred to this group of (mostly fresh-water) plants by Brodie, under the title of N. acuminata. Wainlode Cliff.

Algæ. Fucoidal impressions occur in the bone-beds and shales.

Crustacea.

Phyllopoda. Estheria minuta; a small bivalve, formerly referred by Bronn to Posidonomya; occurs in the upper part of the series, usually in one bed, at Harbury, Garden Cliff, and other localities.

Lophyropoda. Cypris? is mentioned by Strickland in the Estheria bed. The genus is uncertain. Wainlode Cliff, west of Gloucester, &c.

Macrura. Brodie mentions the occurrence of claws and other portions of what is thought to be a species of *Coleia*, a decapod Crustacean.

Mollusca.

Monomyaria. Avicula contorta. *Portlock.*
,, Pecten Valoniensis. *Defrance.*

Dimyaria. Arca, mentioned by *Dr. Wright.*
,, Cardium rhæticum. *Merian.*
,, Cardium cloacinum. *Quenst.*
,, Pullastra arenicola. *Strickland.*
,, Pleurophorus elongatus. *Moore.*
,, Unio. *Brodie.*

FISHES. The names from Agassiz.
Acrodus minimus. Garden Cliff.
Ceratodus altus. Garden Cliff.
Nemacanthus filifer. Garden Cliff.
,, monilifer. Garden Cliff and Combe Hill.
Hybodus minor. Garden Cliff and Combe Hill.
Gyrolepis Alberti. Garden Cliff and Combe Hill.
,, tenuistriatus. Garden Cliff and Combe Hill.
Saurichthys apicalis. Garden Cliff and Combe Hill.

REPTILES.
Ichthyosaurus.
Plesiosaurus. Garden Cliff and Wainlode.

A larger series of fishes and reptiles occurs at Aust Passage, on the Severn, near Bristol, where, in particular, the teeth of Ceratodus were plentifully found by Mr. Higgins. The reptilian remains are very much scattered and often in fragments, much as these and other fossils often occur about the junction-line of deposits, where a remarkable change of life occurs; for example, the bone-bed in the Upper Silurian and another at the base of the mountain limestone.

On considering this list with attention we shall perceive no Cephalopod, no Gasteropod, no Brachiopod, no Echinoderm, no Coral. The shells, though few as to species, are found profusely in certain narrow zones; they are marine, probably belong to shallow water, subject to occasional disturbance during periods of lengthened tranquillity. The disturbances are marked by sandy deposits and detached remains of vertebrata during longer periods: at intervals shoals of small conchiferous mollusks existed. In the upper layers of Monotis decussata and Myacites musculoides the whole period of life of a mollusk is represented; embryonic, young, and full-grown specimens occurring on a plane surface; while the shells of Pullastra arenicola are of nearly uniform age. Pyrites is gathered abundantly about the bones, and is scattered in some of the shales.

The general aspect of the fauna is both liassic and Keüperian; the reptilia are more liassic, the fishes are more Keüperian. Some of the older life remains, some of the newer life has come into view.

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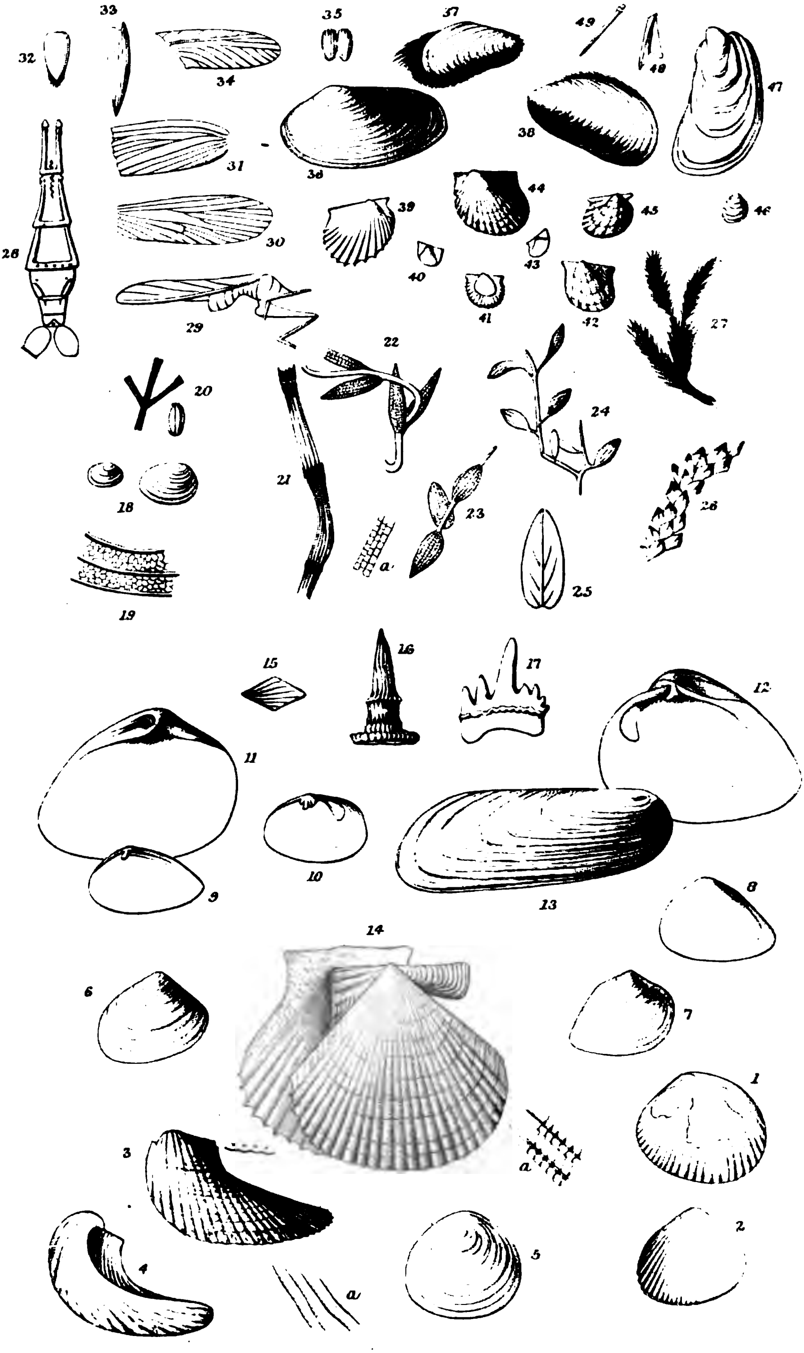
Pl. VII.

RHÆTIC *and* LOWEST LIAS.



Drawn by J. P.
Engraved by J.W.L.

To trace the progress of this newer life through the true lias and oolites is one of the most interesting problems of Palæontology. It is deserving of remark that the shells are generally small, almost dwarfish. But for the difference of size, we should find it not easy to separate the Myacites and Modiolæ, and even the Aviculæ (called Monotis), from species which occur in the lias beds considerably above these which are so closely allied to the rhætics.

REFERENCE TO PLATE VII, CONTAINING FOSSILS OF THE RHÆTIC AND LOWER LIAS STRATA.

In the Bone-Bed Series.

1. Cardium cloacinum. *Quenst.* Westbury.
2. Cardium rhæticum. *Merian.* (Card. Philippianum *Quenst.*)
3. Avicula contorta. *Portlock.* (Gervillia striocurva. *Quenst.*)
4. —— side view.
5. Discina Townsendi. Uphill.

6, 7, 8, 9, 10. Specimens usually referred to Pullastra arenicola of Strickland.

11, 12. Interior, shewing the hinge of opposite valves.

13. Pleurophorus elongatus. *Moore.*
14. Pecten Valoniensis.
15. Scale of Gyrolepis tenuistriatus. *Ag.*
16. Tooth of Saurichthys apicalis. *Ag.*
17. Tooth of Hybodus plicatilis. *Ag.*

From the Estheria Bed.

18. Estheria minuta.
19. Magnified view of the surface.
20. Parts of an umbellate plant. *Buck.*
21. Equisetum Brodiæi. *Buck.*
22. Naiadita lanceolata. *Brod.*
23. Naiadita obtusa. *Buck.*
24. Naiadita petiolata. *Buck.*
25. Leaf of a plant compared to one of the Ericaceæ. *Buck.*
26. Cupressus ? latifolia. *Buck.* Probably a Thuytes or Brachyphyllum.
27. Hippurites ? *Buck.*

From the Lowest Lias Beds.

28[*] Libellula Hopei. *Brodie.* Strensham.

29. Gryllus Bucklandi. *Brodie.* Grafton.
30. Orthophlebia communis. *Westwood.* Wainlode.
31. Chauliodes —— sp. Bidford.
32. Elytra of Dyticus ? *Brodie.* Wainlode.
34. —— Buprestis. *Brodie.* Wainlode.
33. Wing of neuropterous insect. Wainlode.
35. Elytra of Berosus. Westbury.
36. Myacites musculoides (dwarfed). *Geol. Surv.* Westbury.
37. Modiola minima. *Goldf.* Westbury.
38. Do. do. do.

39 to 45. Avicula decussata (Monotis, *Goldf.*) Right and left valves.

46. Young Ostrea liassica. Westbury.
47. Ostrea liassica, young. Westbury.
48. Tooth of Cidaris Edwardsii. *Wright.* Westbury.
49. Spine of Cidaris Edwardsii. *Wright.* Westbury.

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[*] The figures of insects 28–34 are from the valuable volume on Fossil Insects by the Rev. P. B. Brodie, F.G.S.

CHAPTER X.

THE LIASSIC PERIODS.

THE composition of this large succession of clays, limestones, sands, sandstones, ironstones, and jet-bands is much alike throughout England, though all parts of it are liable to much variation in thickness. As already observed, the lowest part of the lias, as it was understood by Smith, Conybeare, and Lonsdale, has now been regarded as distinct enough to bear the separate name of Rhætic. We shall however find it useful, and indeed unavoidable, to keep it in memory while treating of the lias, because the physical history of the earlier deposit is inseparably united with that of the later. Another deviation from the old classification of Smith has been made. The sand which hung over his own house near Bath, and into which he drove curious tunnels for dairy and other uses, giving it the name of 'Sand of the Inferior Oolite,' has been pretty generally transferred to the liassic dominion. We may represent these changes in a diagram :—

INFERIOR OOLITE.

SMITH.	GEOLOGICAL SURVEY.
Sand of the inferior oolite.	Sand of the upper lias.
Upper lias clay.	Upper lias clay.
Marlstone.	Middle lias.
Lower lias clay. Blue lias limestone.	Lower lias, divided into several stages.
White lias.	Rhætic beds.
Black marls, &c.	

RED | MARLS, &c.

Including the group of Westbury shales, as constituting a lower transition zone, and the Midford[a] sands, an upper transition zone, the series contains five great groups:—

Transition Zone.	Midford sands—arenaceous, with sub-calcareous nodules.
True Lias.	Upper lias—Clay or shale, with nodules of ironstone and limestone.
	Middle lias—Ferruginous rock, partly calcareous, partly arenaceous.
	Lower lias—Clays or shales and limestones in many alternations.
Transition Zone.	Westbury or rhætic shales and bone-beds.

Each of the divisions is characterized by peculiar races of ammonites and belemnites, except the lower, which appears to have neither. In the others are several stages or zones of ammonites and belemnites, as well as of fishes and reptiles.

We may now complete the upper part of the fine section at Wilmcote, near Stratford-on-Avon, which in some respects is the most important of all, since it gives in a compact form the series of liassic beds above the Westbury shales, which for convenience are added below:—

Series of Lower Lias Beds.	ft.	in.	
Yellowish clay	2	6	
Limestone, light-coloured. 'Top blocks'	0	9	Dapedius ?
Dark laminated shales	1	8	Ammonites planorbis.
Limestone, light-coloured. 'Bottom blocks'	0	8	
Dark shales	1	6	Am. planorbis.
Limestone, grey. 'Fine course'	0	4	
Dark, finely-laminated shale	1	0	Am. planorbis.
Limestone, grey. 'Mawms'	0	4	
Dark laminated shale	1	0	
Limestone, grey. 'Top whites'	0	4	
Dark shales	1	0	
Limestone, grey. 'Bottom whites'	0	4	
Dark shale	0	8	
Limestone grey. 'Livery beds'	0	2	
Dark shale	0	9	
Limestone, grey. 'Ribs'	0	5	
Dark shale	0	7	
Limestone, grey. 'Hoggs'	0	3	
Dark shale	4	2	

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[a] This title is suggested for these unnamed sands. They were first discovered and studied by Smith, in the picturesque cliff which overhung his house at Tucking Mill, near Midford.

	ft.	in.	
28. Limestone, inconstant	0	6	'Gummerals.' Ostrea liassica.
29. Clay	....		
30. Hard grey limestone	0	6	'Firestone beds.' Saurian remains; Cardium; Modiola minima; Myacites; Ostrea liassica. In this group of beds only one Amm. planorbis has been found.
31. Clay	0	2	
32. Limestone	0	3	
33. Clay	0	2	
34. Limestone	0	3	
35. Clay	0	3	
36. Hard limestone	0 1 to 0	10	'Guinea bed.' Saurian bones; Avicula longicostata; Monotis decussata; Lima punctata; Myacites; Ostrea liassica; Hemipedina Tomesii, frequent; Coral.
Total thickness	23	10¼	

Below are the rhætic beds, containing Avicula contorta, 20 feet 3 inches in thickness.

It will be observed that in this section the classification of the 'Guinea bed' (= 'Monotis bed' at Westbury, = 'Insect bed' at Wainlode) with the lias seems to be well supported by the character of the fossils, here unusually numerous, in this bed. Avicula longicosta, Stutch (= A. cygnipes auctorum), Lima punctata, Hemipedina Tomesii, are quite of liassic affinity. The frequent occurrence of insects in the limestones which lie a few feet above the 'Guinea bed,' with Ostrea liassica, Ammonites planorbis, and Saurians, makes this section valuable for correlating other less clearly determined localities.

No other part of the lower lias in the midland counties is much explored, except for brick-making, and in the few cases of railway cuttings and tunnels. In these situations there is seldom found any considerable series of limestone beds, or even of layers of nodules; in this respect offering a great contrast with the sections of Dorsetshire, where above the thin broad limestone floors like those of Binton and Wilmcote are solid and thick beds with Ammonites Bucklandi, Lima gigantea, Gryphæa incurva, and other fossils never seen in the quarries near Stratford. Yet beds of shale representing these limestones occur in the hills above these quarries, and contain the fossils mentioned, or some of them.

LOWER LIAS.

For a general view, in the midland districts, it is often found useful to adopt a binary division of this thick series, founded on the prevalence of shale in the upper, and of limestone beds in the lower part of the series. The lower portion was again divided by Smith into blue lias above, and white lias beneath; the latter containing few fossils; the distinction being founded on observations in the vicinity of Bath. His white lias was typified about Radstock; his blue lias about Keynsham.

A capital railway section at Saltford, carefully measured by Mr. W. Sanders, affords probably the best view of the blue and white lias in connexion with the Westbury beds which is known in the region of Bath and Bristol.

In the Saltford section about 110 feet of alternating limestones and shales occur, all belonging to the lower part of the lias; the lowest part of all corresponding, but not very accurately, to the Westbury beds.

They may be thus summarized:—

	ft.
f. Beds of limestone and shale containing Belemnites acutus	15
e. Beds of limestone and shale containing Ammonites Bucklandi	10
d. Beds of limestone and shale containing Gryphæa incurva	20
c. Beds of thin flaggy limestone and shale containing few fossils *	40
b. The lower portion, regarded as white lias, rests on a peculiar nodular bed called Cotham marble	
a. Series regarded as equivalent to the Westbury shales, but much more calcareous	25

Pleurotomaria similis occurs in e.
Lima gigantea occurs in c, d, e.
Pholadomya glabra occurs in c, d, e.
Spirifera Walcotti occurs in e.
Ammonites Conybeari occurs in d, e, f.
Rhynchonella variabilis occurs in d, e, f.
Ichthyosaurus occurs in d, e.

The fine fossil formerly known as Plagiostoma (now Lima) gigantea occurs more or less frequently in all the beds of this section which contain ammonites. The whole group of strata has been for this reason not inconveniently called the *'Lima' beds*.

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[*] At Lyme Regis this part of the section yields two zones, one marked by A. angulatus, the other, still lower, marked by A. planorbis. The lowest beds contain no ammonites or belemnites.

The non-ammonitiferous beds below these, but above the Westbury shales, contain in greater abundance than elsewhere Ostrea liassica, and have been called the *Ostrea beds.*

Following the same idea, we may call the lowest (Westbury) group the *Avicula* group, from the frequency in it of A. contorta, a shell which is still more frequent in foreign triassic beds.

Following out the method of marking successive deposits by zones of successive life, and keeping to one of the most characteristic groups (ammonites), we find in the south of England, and partially in the midland district, near Oxford, the following stages (of lower lias) above those noted at Saltford :—

k. Shales usually dark, with Ammonites raricostatus.
i. Shales usually dark, with Ammonites oxynotus.
h. Shales and included bands of grey limestone, with Ammonites obtusus.
g. Shales and limestones, with Ammonites Turneri.

Lima gigantea occurs in g.
Gryphæa obliqua g to k.
Cardinia ovalis in g.
Pentacrinus tuberculatus in g.
Pleurotomaria anglica in h.
Cardinia Listeri in k.

Hippopodium ponderosum in k.
Unicardium cardioides in k.
Rhynchonella variabilis in k.
(k is called the Hippopodium bed by Buckman.)

In these beds Cardinia Listeri and other species of the genus occur pretty frequently, though not uniformly; and following the plan of *grouping* by conchifera, we may apply to them all the title of *Cardinia* beds, marking the *zones* by the most characteristic ammonites. These beds are best seen in detail near Cheltenham; but they are completely traced in mass across Warwickshire and Northamptonshire, between the lima beds and the next great group now to be noticed, viz. the marlstone or middle lias group.

MARLSTONE GROUP.

The middle lias in the midland counties agrees better with the character of that deposit as it occurs in Yorkshire, than with the less rocky and more argillaceous series of Dorsetshire. In Gloucestershire the upper part is a solid ferruginous stone, partly calcareous; the lower part a series of brown, yellow, or grey sands. These are variable, and often thin. There is, in fact, little else in Warwickshire, Oxfordshire, and Northamptonshire but the usually ferruginous rock, called 'marlstone' by William Smith. This rock can be followed step by step in a belt of picturesque buttresses on the western front of the high oolitic region, from the vicinity of Bath, by Wotton-under-Edge, Gloucester, and Cheltenham, to Broadway Hill. Turning round to the east and south, it descends the Vale of the Evenlode, and afterwards holds a picturesque course by Long-Compton to the crest of Edgehill and the plain of Banbury. Here it returns down the valley of the Cherwell, and was observed distinctly about Rowsham and Steeple-Aston by W. Smith in 1805[c]. After this, through a more undulated country, it passes by Daventry towards Belvoir and Grantham, beyond our limits.

It is a mass ten, twenty, or forty feet thick, formed in somewhat irregular, often thin beds, which are traversed by joints as in the oolites. All the associated beds counted, the total thickness in the vicinity of Cheltenham is stated to be 115 feet. Carbonate of iron is diffused through the whole, giving it a brown aspect where air and water have had access; but the stone is often blue in the central parts. Some beds are richly charged with rhynchonellæ, terebratulæ, belemnites, and ammonites; but in considerable tracts of country the fossils are not plentiful. It has been opened for ironstone at Fawler in the Vale of Evenlode, and experiments for the same purpose were tried at Worton and Steeple-Aston. It often contains ten, fifteen, and twenty per cent. of iron. The vicinity of Gloucester and Cheltenham, of Chipping-Campden and Moreton, of Banbury and Edgehill, are good stations for examining the marlstone. Nearer Oxford we have good exposures at Rowsham and Steeple-Aston, where the strata above the rock are very well traceable upward to the white oolite of Hopcroft's Holt. Ammonites spinatus (A. Hawskerensis of Yorkshire) appears to be one of the most characteristic fossils of this zone, for in this district it must count as one, though in Yorkshire and Dorsetshire it may be divided into several.

The section from Rowsham to Hopcroft's Holt, as well as it can now be seen, appears as under :—

Uppermost strata consisting of white calcareous rock, partially oolitic, with bivalve shells. The great oolite 40 feet.

Marly clay, 5 feet.

Sands and sandstone, partly ferruginous, with Astarte minima, 13 feet.

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[c] Memoirs of W. Smith, p. 61.

Upper lias clay, with Ammonites bifrons, A. heterophyllus, A. communis, and Belemnites elongatus, 35 feet.

Marlstone, solid and ferruginous, with Cardium truncatum, Rhynchonella tetraëdra, &c., 20 feet.

Lower lias clay.

Thus the relation of the oolitic and liassic beds—from the great oolite to the lower lias—appears in one hill face of less than 150 feet. At Cheltenham the inferior oolite alone exceeds this thickness, but near Oxford that rock seems to be untraceable.

It is in the marlstone, and in strata almost immediately above it, that the principal part of the liassic iron ore is found. Through a great part of the deposit iron prevails, united with sulphur, or with carbonic acid. Layers of nodules, often having the fissured structure of septaria, occur in most parts of the lias clay, some of which are calcareo-argillaceous, others calcareo-ferruginous. In a general sense the prevalence of iron-carbonate augments as we go northward; it is not remarkable at Lyme Regis, and only becomes prominent in the Oxfordshire district, where also the higher ferruginous bed at the base of the inferior oolite is found worth attention for the iron-furnace. The further north we go, the more does the ferruginous quality of certain layers above the marlstone become conspicuous; till at length on the Yorkshire coast nodular and bedded masses of iron ore appear, eight, eleven, and even sixteen feet thick, and yield what promises to be an inexhaustible supply. When of good quality, three tons of that ore will produce one ton of iron. The marlstone itself is not worked for iron in Yorkshire; but it appears to be only from its reduced equivalent in Oxfordshire that the ore has been obtained.

This rock, always arenaceous but rarely conglomeratic, is not divided by bands of clay, nor are there any layers of limestone, except where the shells (Pectines, Rhynchonellæ, &c.) are so frequent as to make of themselves a calcareous element. An example of conglomerate in marlstone is given by Mr. Hull from a quarry south of Daylesford, the pebbles being slaty and arenaceous, of a Silurian aspect, not exceeding one inch and a half in diameter. The marlstone is extensively used for building and tombstones (Hornton, Chastleton).

Among fossils which are frequent in the marlstone of the midland counties, and occur about Banbury, Stow, and Cheltenham, we have—

Rhynchonella tetraëdra, Terebratula punctata, Avicula novemcostæ, Modiola scalprum, Cardium truncatum, Cardinia crassiuscula, Pholadomya ambigua, Pleurotomaria expansa, Belemnites paxillosus, Ammonites margaritatus, A. spinatus.

UPPER LIAS CLAY.

This deposit, which is barely traceable in a band a few feet thick near Bath, and remains only a few yards thick in the southern parts of Gloucestershire, swells to 80, 100, and even 230 feet in the hills round Cheltenham, as for example in Leckhampton Hill. In Broadway Hill it is about 100 feet, and in the country north of Chipping-Norton 60 to 80 feet. From this point northward the thickness varies, and at length on the coast of Yorkshire reaches 200 or 210 feet.

Taking our station at Cleeve-Cloud (where the upper lias is supposed by Mr. Hull to fall little short of 300 feet in thickness), we may draw a line to the east-north-east, by Shipton and Daventry, through Warwickshire and Northamptonshire, along which the thickness may be taken at about 100 feet; and another at right angles to it by Burford, along which the thickness is found to be continually diminishing, so that at Stow it is 40 feet, at Taynton 20 feet, and at Burford only traceable as a band 6 feet thick[d]. If the line first mentioned be prolonged to the south-west, the great thickness of the upper lias is found to be rapidly diminished, so that at Painswick it is about 80 feet, at Stroud 30 feet, at Wotton-under-Edge 10 feet, and toward Bath a mere parting, between the marlstone and the 'sand of the inferior oolite.'

In the valley of the Evenlode, at Charlbury, the railway cutting discloses the marlstone, upper lias, and inferior oolite, all much reduced in thickness, in a height of 20 feet.

The composition of the upper lias is usually very simple: a nearly uniform, somewhat pale blue clay, with bands and balls of calcareo-argillaceous stone, sometimes a little ferruginous, and generally suited for the manufacture of cement. Balls of this sort lying in the same part of the series are of some value at Whitby, and yield abundance of fossils. These are usually found to have been the centres of aggregation for the concretionary mud. On a smaller scale (as to number) the same facts occur in the hills above Cheltenham and in the districts round Stow and Banbury.

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[d] Hull, in Memoirs of the Geological Survey, 1857.

No bed of sand, no sandstone rock, is intercalated in this series of clay deposits; no mark of current occurs in it, beyond such indications as fragments of wood give: it seems the result of quiet continuous or frequently-repeated sediment, brought by the same cause as that which produced the lower lias shale, and was suspended during the marlstone period of shallower and more agitated water.

MIDFORD SANDS.

The last of the liassic strata, to which the inferior oolite has not quite relinquished its ancient claim, is a variable series of fine sands, deposited on the upper lias clay in such a manner as often to defy the geologist to draw a hard line between them. These sands are bluish underground, yellowish at the surface. They are covered in many districts of the south of England by calcareous and shelly beds, which on the first view appear naturally associated with the oolitic rocks above: but they contain many fossils which are frequent in the sands and not common in the oolites. Thus we have in general terms—

Inferior oolite above.

Shelly calcareous bed.
Fine-grained sands.

Upper lias clay below.

Here then is a transition series of beds, which for convenience and for reasoning may be joined with either or both of the greater deposits which in fact they feebly tie together. On a fuller study of the case we find as a very general fact (at Blue Wick on the Yorkshire coast, in Lincolnshire and Gloucestershire, and at Lyme Regis) that the passage from the clay below to the sand above is by almost insensible gradation; while the oolite above seems to connect itself with equal affinity to shelly calcareous rock at its base. If we wish to draw a hard limit of mineral deposits, it should probably be between the sand and its calcareous cover (which is often absent), but if we desire to study organic sequence, we shall unite the sands and their shelly cap into a transition group.

In this point of view the facts which have come out by inquiry are very instructive. Taking first the group of Cephalopoda, we find some of the well-known species of upper lias to be continued through the sands into the shelly bed above; as Ammonites bifrons, A. opalinus, A. striatulus, A. concavus; Belemnites compressus of Voltz, B. irregularis, B. tripartitus. On the other hand, several conchiferous mollusks which occur with these Cephalopoda have decided oolitic and not liassic affinity. Such are Hinnites abjectus, Trigonia striata, Modiola Sowerbii, Pholadomya fidicula.

Before the liassic life has come to an end the oolitic life has begun; a point of great importance in reasoning on the causes of successive variation in the oceanic population, and one which will come before us again on several occasions while following the course of oolitic time.

The 'Cephalopoda bed,' as Dr. Wright proposes to call the cap limestone of this sandy series, exists where the shells to which it owes its name were specially abundant, or by some natural circumstances were brought together. It is not known in the valleys of the Cherwell or Evenlode, and very partially in any of the branches of the Windrush, Coln, or Churn. But on the western front of the Cotswold cliffs it extends from Cleeve-Cloud to Wotton-under-Edge, appears on the Dorsetshire coast near Bridport, and is recognized in France.

CATALOGUES OF LIASSIC FOSSILS.

In the following catalogues of fossils the species ascertained to belong to the Rhætic beds of Worcestershire and Gloucestershire below, and the cap of sands above, are introduced, to complete the view of liassic life and its connexions. Letters are employed, before the names of places, to mark the stages of the occurrence of the species, viz.:—

S. for the covering sands.
U. for the upper lias.
M. for the middle lias.
L. for the lower lias.
R. for the Rhætic series.

The authorities for the names are given; but it has not been thought necessary to add the special references. The titles of the works of the several authors are given in an earlier page.

FOSSILS OF THE LIASSIC PERIOD.

ACOTYLEDONOUS PLANTS.

Confervites (?). R. Estheria bed, Westbury.
A capsule (?) of a moss. L. Insect limestone, near Gloucester.
Equisetum Brodiæi. *Buckman.* L. Insect limestone, Strensham.

MONOCOTYLEDONOUS PLANTS.

Naiadita lanceolata. *Brodie.* R. Estheria bed, Strensham, and near Bristol.
„ obtusa. *Buck.* R. Same localities.
„ petiolata. *Buck.* R. Same localities.

DICOTYLEDONOUS PLANTS.

Palæozamia obtusa. *Lindley.* L. Insect limestone, Wainlode, Bidford.
„ Bucklandi. *Brong.* L. Insect limestone, Roughton, Strensham, Wilmcote, Bidford.
Pinites, an imperfect cone of. In middle lias, Dumbleton.
Cupressus (?) latifolia. *Buck.* Insect limestone, Strensham.
Brachyphyllum solitarium. n. s. L. Bidford.
Hippurites (?) . . . Insect limestone, Strensham.
Seed of an umbelliferous (?) plant. Insect limestone, Strensham.
Leaf of an ericaceous (?) plant. Insect limestone, Strensham.

This catalogue is taken from a Memoir by Professor Buckman, in the Quarterly Journal of the Geological Society, vol. vi. p. 413, with some additional localities. Nearly all the specimens were obtained from the calcareous beds in the upper part of the Rhætic or Westbury series, including in that term the Estheria bed and the Insect or Monotis bed, already described. Little can be affirmed concerning them beyond the probability of their being partly aquatic, as Naiadita; marsh-loving, as Equisetum (?) and Hippurites (?); and occupiers of drier land, as Otopteris, Cupressus (?), and Pinites. What is called Cupressus may perhaps be ranked with some oolitic conifers under the title of Thuytes or Brachyphyllum. These plants seem to be such as might correspond in relation to climate with the insects which accompany them.

FOSSILS OF THE LIASSIC PERIOD.

FORAMINIFERA.

Cristellaria . . .
Polymorphina . . .
Spirillina infima. Westbury beds, Wainlode.
Other forms occur, not yet determined.

ACTINOZOA.

Isastræa Stricklandi. *Duncan.* L. Chadbury, near Evesham.
  „ Tomesii. *Dunc.* L. Wilmcote.
Lepidophyllia Stricklandi. *Dunc.* L. Chadbury.
Montlivaltia Guettardi. *Dunc.* L. Fenny-Compton.
  „ mucronata. *Dunc.* L. Fenny-Compton, Pebworth.
  „ nummiformis. *Dunc.* L. Fenny-Compton.
  „ patula. *Dunc.* L. Walford, near Stratford-on-Avon.
  „ radiata. *Dunc.* L. Fenny-Compton.
  „ rugosa. *Dunc.* L. Cheltenham, Cherrington, Honeybourn.
  „ Ruperti. *Dunc.* L. Down-Hatherley.
  „ Victoriæ. *Dunc.* M. Cherrington, near Shipston.
Septastræa Haimei. *Dunc.* L. Fladbury, Wilmcote.
  „ Eveshamensis. *Dunc.* L. Evesham.
  „ Fromenteli. *Dunc.* L. Fenny-Compton, Harbury.
Thecocyathus rugosus. *Dunc.* L. Cheltenham, Honeybourn.
  „ Moorei. *Dunc.* L. Aston, near Tewkesbury.
  „ Moorei. sp. L. Fenny-Compton.
Thecosmilia Tarquemi. *Dunc.* L. Binton.

This list of liassic corals, taken from the Monograph of Dr. Duncan, in the Memoirs of the Palæontographical Society, vols. xx. and xxi., with some additional notices by Rev. P. B. Brodie, shews how many unexpected discoveries have been made in unlikely situations. On a first view the liassic limestones and shales, owing to the manner of their laminated and often muddy accretion, seem little likely to yield actinozoan remains. But, in fact, Lyme Regis, Street, Sutton, Evesham, Wilmcote, and Fenny-Stratford have rewarded several investigators of fossil corals. The Monograph of Dr. Duncan shews them to be generically all distinct from the earlier types of the palæozoic age, and for the most part identical with genera of the later oolites. The transverse plates of the old *rugose* corals, and the fourfold division of their calyces is lost, while the newer sixfold division of calyces is not completely established.

In the district now under consideration these corals are found in the lower part of the lias, chiefly in beds associated with Ammonites angulatus, but some are met with in higher zones, especially at Fenny-Compton. Most of the genera are such as might be expected to occur scattered in sea deposits formed at considerable depths, not collected in reefs.

FOSSILS OF THE LIASSIC PERIOD.

ECHINODERMATA.

Crinoidea.

Extracrinus Briareus. *Mill.* L. Horfield near Bristol.

Pentacrinus basaltiformis. *Mill.* L. Badgworth, Frethern, Treddington.
„ Goldfussi. *M'Coy.* L. Mickleton Tunnel.
„ punctiferus. *Quenst.* L. Vale of Gloucester.
„ robustus. *Wright.* M. Hewlett's Hill, Cheltenham.
„ scalaris. *Goldf., Buckm.* L. Vale of Gloucester.
„ tuberculatus. *Mill.* L. Pyrton.

Asteroidea.

Acroura Brodiaei. *Wright.*
Ophioderma Gaveyi. *Wright.* M. Mickleton Tunnel, Hewlett's Hill, Cheltenham.
Ophiolepis Ramsayi. *Wright.* L. Pyrton.
Tropidaster pectinatus. *Wright.* M. Mickleton Tunnel.
Uraster Gaveyi. *Wright.* M. Mickleton Tunnel.

Echinoidea.

Acrosalenia minuta. *Buckm.* L. Cheltenham, Mickleton.
„ crinifera. *Wright.* U. Gloucestershire.
Cidaris Edwardsii. *Wright.* L. Fenny-Compton, Honeybourn. M. Alderton. U. Dumbleton.
Diadema . . . sp. L. Harbury.
Hemipedina Tomesii. *Wright.* L. Wilmcote.
Pedina . . . sp. L. *Wright.* Vale of Gloucester.
Pseudodiadema Moorei. *Wright.* U. Vale of Gloucester.

The whole series of liassic Echinodermata differs generically from the palæozoic predecessors of the group. New crinoids, asteroids, and echinoids mark the advent of these mesozoic strata—a large proportion of the genera are continued into the oolites. It is chiefly to Dr. Wright's Memoirs in the volumes of the Palæontographical Society that we are indebted for our knowledge of the species and their distribution.

FOSSILS OF THE LIASSIC PERIOD.

ARTICULATA.

Annellida.

Serpula plicatilis. *Goldf.* M. Uley, Gloucestershire. O. G. S.
„ flaccida. *Goldf.* M. Stinchcombe, Gloucestershire. O. G. S.
„ limax. *Goldf.* L. Vale of Gloucester.
„ socialis. *Goldf.* L. Fenny-Compton.

Cirripedia.

Pollicipes. L. Mickleton Tunnel.

Crustacea.

C. Isopoda. Aega. L. Mickleton.
C. Entomostraca. Estheria minuta. R. Westbury, Wainlode, Harbury, &c.
Cytherina liassica? L. Down Hatherley.
C. Decapoda Macroura. Coleia. R. Westbury Cliff. U. Gloucestershire.
Eryon Barrovensis. *M'Coy.* L. Wilmcote. M. Dumbleton.

C. Decapoda Macroura. Glyphea liassina. *Woodward.* L. Saltford, near Bath.
„ sp. L. Mickleton Tunnel.
Hippolite. sp. U. Dumbleton.
Hoploparia. sp. L. Wainlode Cliff.
Scapheus ancylochelis ? *Wood.* L. Tewkesbury.

The contrast between these crustaceans and annelids and those of the older systems of life is very decided. The numerous trilobites have passed away, and are succeeded by the tribes of long-tailed ten-footed lobsters and prawns. The Entomostracous genera, however (Estheria and Cytherina), continue and go on in the series of strata. As yet no proof of the short-tailed races of crabs.

The shell-covered cephalobranchiate annellida (Serpula, &c.) which were rare in the older deposits now become frequent.

FOSSILS OF THE LIASSIC PERIOD.

INSECTA.

Coleoptera.

Buprestidæ (?). Elytra. L. Strensham, Wainlode, Apperley, Brockeridge, Churchdown.
Curculionidæ (?). Elytra. L. Hasfield.
Carabidæ. Elytra. L. Apperley, Brockeridge.
Telephoridæ. Elytron. L. Forthampton.
Laccophilus aquaticus. Elytra. L. Hasfield.
Elater vetustus. L. Apperley.
Gyrinus (?). L. Forthampton.
Chrysomelidæ (?). L. Forthampton.
Melolontha (?). Abdomen. L. Cracombe, Worcestershire.

Orthoptera.

Gryllus Bucklandi. L. Grafton, Warwickshire.
Gryllidæ. Legs. L. Forthp
Blattidæ (?). Tegmina. L. Wainlode, Strensham.

Hemiptera and Homoptera.

Cicada Murchisoni. L. Hasfield.
Homopterous insect. L. Hasfield.
Cimicideous insect. L. Strensham.

Neuroptera.

Libellula Brodiei. *Buck.* U. Dumbleton.
„ dislocata. U. Dumbleton.
„ Hopei. L. Strensham.
„ liassina. *Strickl.* L. Bidford.
Agrion Buckmanni. U. Dumbleton.
Orthophlebia communis. *Westwood.* L. Wainlode, Forthampton, Strensham, Cracombe, Bidford.
Chauliodes. Wings. L. Hasfield, Strensham, Bidford.
Ephemera. Wing. L. Strensham.

Diptera.

Asilus (?) ignotus. L. Forthampton.

For the discovery of these curious fossils geology is indebted mainly to the Rev. P. B. Brodie, whose excellent work on Fossil Insects was issued in 1845. The above list is taken from his volume principally. The names are his except in one or two cases. Professor Westwood examined the whole series. On the whole, there is a large proportion of Neuropterous insects with wings well preserved, and several families of Coleoptera, mostly terrestrial. We may believe the whole group to belong to a temperate climate, and to have been blown or drifted into shallow sea water from the palæozoic regions, which have been already proved to have been elevated on the west. The process began in the Rhætic period, for some allied forms occur in the landscape stone of Aust, and we shall find it to have been continued into the oolitic ages.

FOSSILS OF THE LIASSIC PERIOD.

Polyzoa.

Specimens have been observed on shells—on Gryphæa at Fenny-Compton.

Brachiopoda.

Discina Townsendi. *Forbes*. L. Vale of Gloucester.
„ sp. L. Leckhampton.
Lingula Beanii. *Phil.* L. Stonehouse (O. G. Survey). M. Stinchcombe, Mickleton.
Rhynchonella acuta. *Sow.* L. Fenny-Compton. M. Alderton, Dumbleton, Bredon.
„ bidens. *Phil.* M. Alderton, Dumbleton, Bredon.
„ furcillata. L. Near Stow.
„ Moorei. *Dav.* L. Aston, near Tewkesbury.
„ oxynota. *Geol. Surv.* L. Aston, near Tewkesbury.
„ rimosa. *Von Buck.* L. Stonehouse, Fenny-Compton.
„ subconcinna. *Dav.* M. Near Kineton.
„ tetraëdra. *Sow.* M. Bredon, Fawler, Aynhoe, Banbury, &c.
„ variabilis. *Schlot.* L. Stonehouse, Harbury. M. Dumbleton, Alderton, Mickleton.
Spirifera Munsteri. *Dav.* L. Stonehouse.
„ rostrata. *Sow.* L. Stonehouse, Fenny-Compton. M. Gretton, Dumbleton.
„ Walcotti. *Sow.* L. Aston, Fenny-Compton.
Terebratula cornuta. *Sow.* M. Chipping-Campden, Dumbleton, Alderton.
„ cynocephala. *Rich.* S. Leckhampton.
„ Edwardsii. *Dav.* M. Gretton.
„ indentata. *Sow.* M. Banbury, Deddington.
„ numismalis. *Lam.* L. Fenny-Compton. U. Cheltenham.
„ perforata. L. Fenny-Compton.
„ punctata. *Sow.* L. Stonehouse. M. Deddington, Fawler, Frocester, &c.
„ resupinata. *Sow.* M. Bredon, Deddington, Byfield, Mickleton.
„ subdecorata. *Dav.* S. Leckhampton.
„ subpunctata. *Dav.* S. Frocester, Nailsworth.

The above list would be considerably enlarged by counting in the species found by Mr. Moore near Ilminster, and by receiving as species some of the many varieties which solicit attention among Rhynchonellæ and Terebratulæ. It will be remarked that nearly all the localities are in the lower or the middle lias; there are, however, three or four species admitted by the Geological Survey from the upper lias, the cap of sands, and the cephalopodal bed.

All the genera were known in the palæozoic strata, and all excepting Spirifera are frequent in the oolites and later deposits.

On comparing specimens *which might be selected* from the lias and others from the carboniferous limestone and earlier strata, it would be possible to find no obvious external difference; and there is seldom an opportunity to examine the interior, so as to compare the loops of Terebratula and the prominent plates of Rhynchonella. When so examined there is some difference, but it appears small in comparison of the immensity of elapsed time and the total difference in representatives of other classes of animals.

FOSSILS OF THE LIASSIC PERIOD.

CONCHIFERA.

Monomyaria.

Anomia attached to Crenatula. L. Near Stow.
Avicula contorta. *Portl.* R. Wilmcote.
„ cygnipes. *Phil.* L. Chadbury near Evesham, Horfield, Banbury, &c. M. Dumbleton.
„ longiaxis. *Buckm.* L. Battledown.
„ novemcostæ. *Brown.* L. Fenny-Compton, Mickleton. M. Shotswell near Banbury.
Crenatula ventricosa. *Sow.* L. Fenny-Compton, Cheltenham. M. Dumbleton.
Gastrochæna tortuosa. *Phil.* L. Banbury.
Gervillia crassa. *Buckm.* L. Bredon, Banbury.
„ fornicata. *Lycett.* S. Nailsworth.
„ Hartmanni. *Munst.* S. Nailsworth, Frocester, Leckhampton.
„ lævis. *Buckm.* L. Cheltenham, Mickleton.
Gryphæa gigantea. *Sow.* M. Stinchcombe, Churchdown, Dumbleton.
„ incurva. *Sow.* L. Frethern, Fenny-Compton, Harbury.
„ MacCullochii. *Sow.* L. Cheltenham. M. Stow.
„ obliquata. *Sow.* L. Fenny-Compton, Gretton.
Hinnites abjectus. *Phil.* M. Byfield. S. Frocester, Nailsworth.
Inoceramus dubius. *Sow.* M. Bredon. U. Dumbleton.
Lima antiquata. *Sow.* L. Fenny-Compton.
„ bellula. *Lycett.* S. Frocester, Nailsworth.
„ duplicata. *Sow.* M. Gretton, Mickleton.
„ electra. *D'Orb.* S. Frocester, Nailsworth.
„ gigantea. *Sow.* L. Fenny-Compton, Wilmcote.

Lima Hermanni. *Voltz.* L. Horfield, Abbotswood, Fenny-Compton. M. Alderton, Dumbleton, Stow.
  „ Omaliusii. *Geol. Surv.* M. Nibley.
  „ ornata. *Lycett.* S. Nailsworth.
  „ pectinoides. *Sow.* L. Wilmcote, Bidford, Mickleton.
  „ punctata. *Sow.* L. Wilmcote, Defford.
Monotis decussata. *Goldf.* R. Westbury, Wilmcote.
  „ papyracea. . . . L. Rugby.
Ostrea irregularis. *Geol. Surv.* L. Down Hatherley.
  „ læviuscula. *Sow.* L. Frethern, Cheltenham.
  „ liassica. *Strick.* L. Combe Hill, Brockeridge, Bidford.
Pecten æquivalvis. *Sow.* L. Mickleton. M. Dumbleton, Stinchcombe, Aston-le-Walls.
  „ articulatus. *Goldf.* S. Frocester.
  „ cinctus. *Sow.* M. Cheltenham, Mickleton.
  „ cingulatus. *Goldf.* M. Stinchcombe, Dumbleton.
  „ comatus. *Goldf.* S. Nailsworth.
  „ dentatus. *Sow.* M. Rugby.
  „ paradoxus. *Geol. Surv.* M. Stinchcombe, Long Compton.
  „ Pradoanus . . . L. Fenny-Compton, Harbury.
  „ sublævis. *Phil.* L. Cheltenham, Banbury, Mickleton. M. Bredon.
  „ textorius. *Schl.* L. Frethern, Cheltenham. M. Aston-le-Walls, Banbury. S. Frocester.
  „ Thiolieri . . . L. Fenny-Compton.
  „ Valoniensis. *Defr.* R. Westbury.
  „ velatus. . . . L. Cheltenham. M. Dumbleton.
Perna rugosa. *Goldf.* S. Nailsworth.
Pinna fissa. *Goldf.* L. Cheltenham, Battledown. M. Stinchcombe.
  „ folium. *Phil.* L. Banbury.
  „ Hartmanni. *Goldf.* M. Bredon, Churchdown, Dumbleton, &c.
Plicatula sarcinula. *Goldf.* L. Vale of Gloucester. M. Stinchcombe.
  „ spinosa. *Sow.* L. Cheltenham, Fenny-Compton. M. Alderton Dumbleton.

Several of these genera have been already mentioned in catalogues of earlier deposits; but Crenatula, Gervillia, Gryphæa, Ostrea, Plicatula are conspicuous exceptions. What are here entitled Monotis may as well be ranked with Avicula. The species of Gryphæa are not sufficiently defined, but the form G. incurva Sow. (arcuata Lam.) is usually the lowest and oldest of the group. G. gigantea recurs in the oolite above. Ostrea liassica is found in the lowest beds of the lias. There appear to be other species of Pecten, according to Professor Buckman, in the lower and middle lias.

FOSSILS OF THE LIASSIC PERIOD.

CONCHIFERA.

Dimyaria.

Arca Buckmanni. *Rich.* L. Battledown.

Arca elongata. *Buckm.* L. Stonehouse, Chipping-Campden. M. Nibley.
„ truncata. *Buckm.* L. Stonehouse, Battledown, Mickleton. M. Stinchcombe.
Astarte complanata. *Röm.* S. Nailsworth.
„ excavata. *Sow.* S. Frocester, Nailsworth.
„ lurida. *Sow.* S. Nailsworth, Stow.
„ modiolaris. *Wright.* S. Nailsworth.
„ ovalis. *Geol. Surv.* L. Stonehouse.
„ rugulosa. *Lycett.* S. Nailsworth.
„ Voltzii. *Geol. Surv.* M. Stow.
Cardinia attenuata. *St.* L. Cheltenham, Stow, Fenny-Compton.
„ concinna. *St.* M. Daventry.
„ crassissima. *Sow.* M. Wotton-under-Edge, Mickleton.
„ crassiuscula. *Sow.* L. Cheltenham, Mickleton.
„ lanceolata. *St.* L. Mickleton.
„ Listeri. *Sow.* L. Cheltenham.
„ ovalis. *St.* L. Frethern, Ashelworth.
Cardium cloacinum. *Quenst.* R. Westbury.
„ Hullii. *Wright.* S. Frocester, Nailsworth.
„ multicostatum. *Phil.* M. Dumbleton.
„ Rhæticum. R. Westbury.
„ truncatum. *Sow.* L. Chipping-Campden, Banbury. M. Stinchcombe, Bredon, Wotton-under-Edge, &c.
Ceromya lineata. *Geol. Surv.* L. Hayford.
Corbis uniformis. *Phil.* L. Banbury, Stow. M. Nibley.
Cucullæa ferruginea. *Geol. Surv.* S. Nailsworth, Wotton-under-Edge.
„ oblonga. *Sow.* S. Leckhampton.
Cypricardia cordiformis. *Desh.* S. Frocester.
„ brevis. *Wright.* S. Frocester, Nailsworth.
Goniomya angulifera. *Sow.* S. Frocester, Leckhampton.
„ literata. *Geol. Surv.* L. Chipping-Campden. M. Bredon, Alderton, &c.
Gresslya abducta. *Phil.* L. Hayford. S. Frocester, Nailsworth, Leckhampton.
„ anglica. *Agas.* L. Chipping-Campden.
„ coniformis. *Ag.* S. Frocester, Nailsworth.
Hippopodium ponderosum. *Sow.* L. Banbury, Fenny-Compton, Bredon, Cleeve.
Homomya. . . . sp. M. Gretton.
Leda complanata. *Phil.* L. Stonehouse, Chipping-Campden.
„ lachryma. *Sow.* L. Defford, Bredon.
„ ovum. *Sow.* L. Eyden, Northamptonshire.
„ rostralis. *Lam.* L. Cheltenham, Fenny-Compton. U. Dumbleton.
Lucina L. Bredon. M. Dumbleton.
Lutraria gibbosa. M. Bredon.
„ ovata. Wotton-under-Edge.
Modiola cuneata. *Sow.* L. Chipping-Campden, Stonehouse, Battledown.
„ Hillana. *Sow.* L. Berkley Heath, Deddington. M. Winchcombe.
„ minima. *Sow.* L. Wainlode, Coltknap, &c.
„ scalprum. *Sow.* L. Banbury, Mickleton. M. Bredon, Cheltenham, Stinchcombe.
„ Sowerbyana. *D'Orb.* S. Frocester.
Myacites donaciformis. *Phil.* L. Stow, Banbury. M. Dumbleton, Bredon.

Myacites liassicus. *Brod.* L. Fenny-Compton.
  ,, musculoides. *Geol. Survey.* R. Westbury.
  ,, tenuistriatus. *Ag.* S. Frocester, Nailsworth.
  ,, unionides. *Geol. Surv.* M. Tewkesbury, Dumbleton, Stinchcombe.
Myoconcha crassa. *Sow.* S. Nailsworth.
Mytilus hippocampus. *Geol. Surv.* L. Berkley Heath. M. Nibley.
Nucula globosa. M. Stinchcombe.
  ,, ovalis. *Zieten.* S. Nailsworth.
Opis carinata. *Wright.* S. Frocester.
Pholadomya ambigua. *Sow.* L. Bredon, Cheltenham, Fenny-Compton, Mickleton. M. Dumbleton, Stow.
  ,, decorata. *Goldf.* L. Cheltenham.
  ,, fidicula. *Sow.* S. Frocester, Nailsworth, Leckhampton.
  ,, obliquata. *Phil.* L. Banbury.
  ,, ovulum. *Ag.* S. Nailsworth.
Pleurophorus elongatus. *Moore.* R. Westbury.
Pullastra arenicola. *Strick.* R. Westbury, Wilmcote.
Sanguinolaria striata. *Geol. Surv.* M. Stinchcombe.
Trigonia Ramsayi. *Wright.* S. Frocester, Leckhampton.
  ,, striata. *Sow.* S. Frocester, Nailsworth.
Unicardium cardioides. *Phil.* L. Fenny-Compton, Chipping-Campden. M. Dumbleton, Bredon, Stow.
  ,, varicosum. *Geol. Surv.* M. Stow, Dumbleton. S. Nailsworth.

Differing on the whole very much from the conchifera of the palæozoic formations, by the prevalence of Astarte, Cardinia, Corbis, Hippopodium, and Pholadomya, which are unknown in them, we find the continuity of life in the many-toothed genera like Arca and Cucullæa, which with Modiola and Sanguinolaria constitute a considerable part of the early Dimyarian mollusks. Pullastra must be regarded as of uncertain designation, and Myacites is an indefinite group of species. Ceromya, Goniomya, Gresslya, Homomya, and Pholadomya, which begin their career in the lias, have more oolitic than liassic species.

FOSSILS OF THE LIASSIC PERIOD.

GASTEROPODA.

Acmæa. sp. M. Uley.
Actæon. sp. L. Aston.
Cerithium lineatum. L. Stonehouse, Cracombe, Aston.
Chemnitzia. sp. U. Vale of Gloucester.
  ,, Zinkeni. L. Fenny-Compton.
Conus semicostatus (?). *Goldf.* M. Dumbleton.
Dentalium angulatum. *Buckm.* M. Alderton, Dumbleton.
  ,, minimum. *Strick.* L. Cracombe.
Littorina. sp. L. Bredon, Aston.
Natica. sp. U. Vale of Gloucester.

Pleurotomaria anglica. *Sow.* L. Bredon, Cleeve, Stonehouse, Stow, Banbury.
„ expansa. *Sow.* L. Chipping-Campden, Banbury. M. Bredon, Alderton, Dumbleton.
„ rotellæformis. M. Cheltenham.
Rotella compressa. *Sow.* M. Dumbleton, Alderton.
Tornatella. sp. M. Stow. L. Stonehouse.
Trochus bisertus. *Phil.* U. Dumbleton, Chipping-Campden.
„ imbricatus. *Sow.* L. Cheltenham, Mickleton.
Turbo capitaneus. *Munst.* S. Frocester, Nailsworth.
„ heliciformis. *Geol. Surv.* L. Fenny-Compton, Aston.
„ sculptus? *Sow.* M. Dumbleton, Alderton.
„ solectus. *Geol. Surv.* L. Cheltenham.

The small number of liassic gasteropoda would be a subject of surprise if we did not call to mind the argillaceous nature of the strata and the circumstances of their deposition. The muddy parts of existing seas are not the favourite haunts of these animals, which on the whole prefer shallow water and stony, sandy, and weedy shores. The naturalist will remark the rarity, if not the absence, of the zoophagous genera, included in the division called 'Siphonostomata.' The fossil referred (with doubt) to Conus semicostatus by Buckman appears an exception: Cerithium is now classed in the Holostomatous division of Mollusca.

FOSSILS OF THE LIASSIC PERIOD.

CEPHALOPODA.

Ammonites angulatus. *Schlot.* L. Frethern, Harbury, Fenny-Compton.
„ anguliferus. *Phil.* L. Cheltenham.
„ armatus. *Sow.* L. Cheltenham, Honeybourn, Mickleton.
„ accipitris. *Buck.* L. Cheltenham.
„ Aalensis. *O. G. S.* U. Frocester.
„ acuticosta. *Strick.* L. Near Evesham.
„ annulatus. *Sow.* U. Dumbleton.
„ bifrons. *Brug.* U. Dowdeswell, Steeple-Aston. S. Frocester.
„ Bucklandi. *Sow.* L. Keynsham, Defford.
„ Bodleyi. *Buck.* L. Bredon, Southam.
„ Bonardi. *D'Orb.* L. Bredon.
„ Boblayi. *D'Orb.* L. Cheltenham, Southam.
„ Brodiæi. *Sow.* L. Bredon.
„ Birchii. *Sow.* L. Bredon.
„ Brooki. *Sow.* L. Bredon.
„ concavus. *Sow.* S. Frocester.
„ Conybeari. *Sow.* L. Saltford.
„ Carusensis. *D'Orb.* L. Cheltenham.

Ammonites catenatus (= angulatus). *Sow.* L. Cheltenham.
„ communis. *Sow.* L. Fenny-Compton.
„ canaliculatus. *Brown.* M. Dumbleton.
„ capricornus. *Schlot.* L. Cheltenham.
„ centaurus. *D'Orb.* L. Cheltenham.
„ corrugatus. *Sow.* M. Dumbleton.
„ Coynarti. *D'Orb.* L. Cheltenham.
„ Dewalquianus. *D'Orb.* S. Frocester.
„ discoides. *Zieten.* S. Frocester.
„ Engelhardti. *D'Orb.* M. Winchcombe, Stinchcombe.
„ erugatus. *Bean.* L. Vale of Gloucester.
„ elegans. *Sow.* L. Vale of Gloucester.
„ fimbriatus. *Sow.* M. Banbury.
„ Fowleri. *Buck.* L. Vale of Gloucester.
„ falcifer. *Sow.* U. Dumbleton, Banbury.
„ forficatus. *Strickl.* L. Eckington.
„ Guibalianus. *D'Orb.* L Cheltenham.
„ Greenovii. *Sow.* L. Cheltenham.
„ halecis. *Buck.* L. Vale of Gloucester, Southam.
„ Henleyi. *Sow.* L. Cheltenham, Stonehouse, Fenny-Compton, Stow.
„ heterophyllus. *Sow.* M. Dumbleton, Alderton. U. Steeple-Aston.
„ hircinus. *Schl.* S. Frocester.
„ hybridus. *O. G. S.* M. Stow.
„ insignis. S. Nailsworth, Frocester.
„ Jurensis. *Zieten.* S. Frocester, Nailsworth.
„ lævigatus. *Sow.* L. Ashton.
„ lacunatus. *Buck.* L. Vale of Gloucester.
„ laticostatus. *Sow.* L. Cheltenham.
„ Leckenbyi. *Wright.* S. Frocester.
„ Levesquii. *D'Orb.* S. Frocester.
„ Loscombi. *Sow.* L Cheltenham.
„ multicostatus. *Sow.* L. Fenny-Compton.
„ margaritatus. *Montf.* L. Banbury. M. Dumbleton, Bredon.
„ Moorei. *O. G. S.* U. Frocester.
„ maculatus. *Y.* and *B.* L. Bredon.
„ nodulosus. *Buck.* L. Cheltenham.
„ obtusus. *Sow.* L. Bredon, Cleeve.
„ opalinus. *Rein.* S. Frocester, Leckhampton.
„ ophioïdes. *D'Orb.* L. Cheltenham, Bredon.
„ ovatus. *Y.* and *B.* U. Dumbleton.
„ oxynotus. *Quenst.* L. Stonehouse, Cheltenham.
„ planorbis. *Sow.* L. Cheltenham, Wilmcote, Bidford.
„ planicostatus. *Sow.* L. Mickleton. M. Glenfall, near Cheltenham.
„ radians. *D'Orb.* S. Frocester.
„ raricostatus. *Sow.* L. Cheltenham.
„ rotiformis. *Sow.* L. Cheltenham.
„ Raquinianus. *D'Orb.* U. Stow. S. Frocester, Nailsworth.
„ serpentinus. *D'Orb.* U. Dumbleton, Stroud.
„ Sauzianus. *D'Orb.* L. Horfield.
„ spinatus. *Brug.* M. Stinchcombe, Dumbleton.

Ammonites solaris. *Phil.* U. Westcombe (Glouc.).
„ Smithii. *Sow.* L. Vale of Gloucester.
„ Stokesi. *Sow.* M. Alderton, Dumbleton.
„ striatulus. *Sow.* S. Frocester.
„ subarmatus. *Sow.* L. Vale of Gloucester.
„ sulcatus (angulatus ?). *Buck.* L. Cheltenham.
„ tortilis. *D'Orb.* L. Cleeve.
„ Taylori. *Sow.* L. Cheltenham.
„ Thouarsensis. *D'Orb.* U. Stroud. S. Frocester.
„ torulosus. *Schul.* S. Leckhampton.
„ Turneri. *Sow.* L. Bredon.
„ Valdani. *D'Orb.* L. Cheltenham.
„ variabilis. *D'Orb.* S. Frocester, Nailsworth.
„ Ziphus. *O. G. S.* L. Cheltenham.
Belemnites acutus. *Miller.* L. Cheltenham, Fenny-Compton, Shipston.
„ acuarius. *Schl.* L. Cheltenham.
„ clavatus. *Blainville.* L. Cheltenham, Stow, Mickleton.
„ compressus. *Stahl. O. G. S.* M. Stinchcombe. U. Stinchcombe.
„ elongatus. *Sow.* M. Stow, Deddington, Mickleton.
„ Fournelianus. *D'Orb.* M. Stinchcombe.
„ irregularis. *Schl.* S. Frocester, Nailsworth.
„ paxillosus. *Schl.* L. Banbury, Deddington. M. Wotton, Byfield.
„ penicillatus. *Sow.* L. Cheltenham.
„ tripartitus. *Schl.* S. Frocester, Nailsworth.
„ Voltzii. *Phil.* S. Frocester, Nailsworth.
Aptychus. sp. L. Warwickshire.
Ink bag. U. Dumbleton.
Geoteothis. U. Dumbleton.
Acanthoteuthis speciosa. U. Dumbleton.
Nautilus inornatus. *D'Orb.* M. Dumbleton. U. Stinchcombe. S. Frocester, Leckhampton.
„ intermedius. *Sow.* L. Rugby, Deddington.
„ lineatus. *Sow.* L. Bath.
„ semistriatus. *Sow.* L. Bredon.
„ striatus. *Sow.* L. Bredon, Cleeve. M. Mickleton.

The liassic deposits are the richest of all the strata in ammonites and belemnites, and the zeal of collectors, by procuring them of all ages and under different circumstances, has given occasion to coin too great a number of specific names. Yet, for the most part, the diversity of names for a given set of forms indicates something really different in the history of the species, and most of the designations may be retained as marking varieties worth discrimination. In making, some years since, a strict comparison of the ammonites of the Yorkshire lias with others from the south of England esteemed to be of the same species, I found often some small differences, especially in the sutures, which might be best understood as local peculiarities of race. Ammonites to be really known as species, must be studied with many examples of every age, including the very young and the very old; the change of form in the course of life being often very great and remarkable.

In considering the large list of species here presented, the student will find himself obliged to gather them into groups of allied forms: when this is done he will find the groups to be on the whole differently related to geological time; so that 'zones' of ammonitic life appear one above another in place, one after another in time.

For example, choosing first ammonites which are carinated round their whorls, we may mark three groups and assign to each its geological 'habitat.'

3. Keel acute simple (falciferi)	Upper lias.
2. Keel serrated (amalthei)	Middle lias.
1. Keel between two furrows (bisulcati)	Lower lias.

And these characters are applicable to the north and the south of England, to France and Germany.

The relation to time is, however, not so absolute, but that exceptions arise which are interesting to consider.

In the first group, of bisulcate ammonites, occurs one species which belongs to upper lias, viz. Ammonites bifrons.

The second group has a remarkable recurrence in the middle oolite series, where Ammonites vertebralis is a conspicuous fossil.

The third group is continued into the sands which cap the upper lias, and into strata a little above them, which constitute the lower part of the inferior oolite of Dundry. Even in the Stonesfield slate we find falciferous ammonites.

Again, if we take another series of ammonites without keel or furrow on the whorl, we may mark three groups of forms and assign three parallels of geological time.

3. Discoid with divided ribs (planulati) . . .	Upper lias.
2. Discoid with undivided ribs (capricorni) . .	Base of middle lias or upper part of lower lias.
1. Discoid with nearly smooth surface (planorbes) .	Base of the lower lias.

Tables of this kind are found of great value in making comparisons between far separated liassic deposits. More than this, particular species have been selected to mark more than the three or six zones here indicated, and with considerable success. In this ammonitic chronology the first important step was taken, half a century since, by W. Smith, who composed a table of ammonites, in natural groups, and referred them one by one to their appropriate seats in the strata. But the table remained in MS. in the hands of his amanuensis till 1860, when it was printed as part of the address delivered by him as President of the Geological Society. Von Buch in 1832 prepared a famous treatise on ammonitic characters and groups, and his results have had a great influence on all subsequent efforts. In Germany, Professors Oppel and Quenstedt, in England, Dr. Wright, have been most successful in marking out liassic 'zones' by ammonitic species, and have in fact furnished a 'chronology' of great value, which, cautiously applied, helps and will help in all investigations into even far-separated tracts of liassic deposits[e].

The same method applied to belemnites yields very similar and not less assured results[f].

It ought to be applied in all cases of large natural groups; we should have zones of Echinodermata, Brachiopoda, &c. treated *independently* of the Cephalopoda, with which they would not necessarily synchronize; and finally all would be combined into a true system of geological chronology. This is in progress. Meantime, in the following Table we have marked a series of ammonitic species more or less limited to the several epochs, and in another column appear other nearly contemporaneous forms of life. The whole liassic period, comprising the Rhætic shales below and the Cephalopodal bed above, is included to make the view complete.

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[e] See in particular Oppel's Jura, Quenstedt's Jura, Wright's memoirs in Pal. Soc. volumes.

[f] See my memoir on Belemnites in Pal. Soc. volumes.

DISTRIBUTION OF SOME FORMS OF LIASSIC LIFE.

UPPER LIAS.	Cephalopodal bed.		
	Midford sands	*A. opalinus.	*Belemnites irregularis.
	Upper lias clays and balls	*A. communis.	Belemnites Voltzii.
		*A. bifrons.	
		*A. serpentinus.	
		*A. heterophyllus.	
			*Belemnites elongatus.
MIDDLE LIAS.	Marlstone†	*A. spinatus.	*Pecten æquivalvis.
		*A. margaritatus.	*Belemnites paxillosus.
			*Cardium truncatum.
LOWER LIAS.	Lower lias clays and balls	*A. Henleyi.	
		A. raricostatus.	*Hippopodium ponderosum.
		A. oxynotus.	
		*A. obtusus.	*Cardinia Listeri.
		A. Turneri.	
	Lias limestone and shales	*A. Bucklandi.	*Belemnites acutus.
		*A. angulatus.	*Lima gigantea.
			Ichthyosaurus intermedius.
			Plesiosaurus megacephalus.
		*A. planorbis.	*Ostrea liassica.
	Rhætic beds		*Avicula contorta.

FOSSILS OF THE LIASSIC PERIOD.

PISCES.

Acrodus minimus. R. Westbury.
Aechmodus angulifer. L. Near Stratford.
Aechmodus dorsalis. L. Byrford, Gloucestershire.
Ceratodus altus. R.
Dapedius orbis. L. Bidford.
Gyrolepis Alberti. R. Wickwar.
„ tenuistriatus. R. Westbury.
Hybodus minor. R. Westbury.
Leptolepis concentricus. U. Dumbleton.
Nemacanthus filifer. R. Westbury.
„ monilifer. R. Aust, Westbury, &c.
Pachycormus latirostris (?). U. Gloucestershire.
Pholidophorus crenulatus. U. Dumbleton.
Pholidophorus Stricklandi. L. Bidford.
Saurichthys apicalis. R. Westbury.
Tetragonolepis discus. U. Dumbleton.

Of the fishes here mentioned some are *Placoid*, and allied to sharks. Such are Acrodus and Ceratodus, known only by teeth;

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* The fossils marked thus are figured in Plates VII. and VIII.

† In the district around Oxford it is not satisfactory to mark off, as belonging to the middle lias, any of the argillaceous beds below the marlstone. In Yorkshire and on the Dorsetshire coast the case is somewhat different. These beds below the principal mass of marlstone include Ammonites capricornus, Jamesoni, fimbriatus, Henleyi.

Nemacanthus, known only by spines; and Hybodus, of which spines and teeth are known. Others are *Ganoid,* as Leptolepis and Gyrolepis, known only by scales; Aechmodus, Dapedius, Pholidophorus, and Tetragonolepis, which are in a state of completeness. Lepidotus occurs complete in Northamptonshire. Saurichthys has left only teeth. The nomenclature is that of Agassiz.

REPTILIA.
Ichthyosaurus communis. *Conyb.* L. Wilmcote.
„ intermedius. *Conyb.* L. Near Tewkesbury.
,, tenuirostris. *Conyb.* L. Near Tewkesbury.
Plesiosaurus megacephalus. L. Wilmcote.
Dimorphodon (coracoid). *Wright.* U. Gloucestershire.
„ bone of. *Buckm.* M. Dumbleton.
Teleosaurus. sp. *Wright.* U. Gloucestershire.

The small number of reptiles in this list corresponds with the limited extent of workings in the lias. Farther to the north, at Barrow-on-Soar, and to the south, at Street near Glastonbury, the lias limestones, of the same early age as those of Wilmcote and Bidford near Stratford, appear to be more productive of Saurians; and the greater richness of the cliffs of Whitby and Lyme Regis, in beds somewhat higher in the series, is well known. The species of Ichthyosauri are by no means fully defined at present. The best specimens from the Warwickshire district are at Warwick and Oxford, and have been examined with some care. The diagram above represents paddles of the species supposed to be Ichthyosaurus intermedius, but they differ from others which bear the name in the emargination of the radial and phalangal bones.

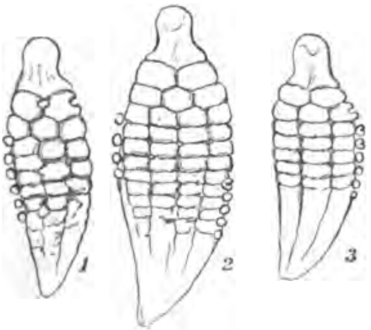


Diagram XXVI. Paddles of Ichthyosaurus, from Wilmcote.

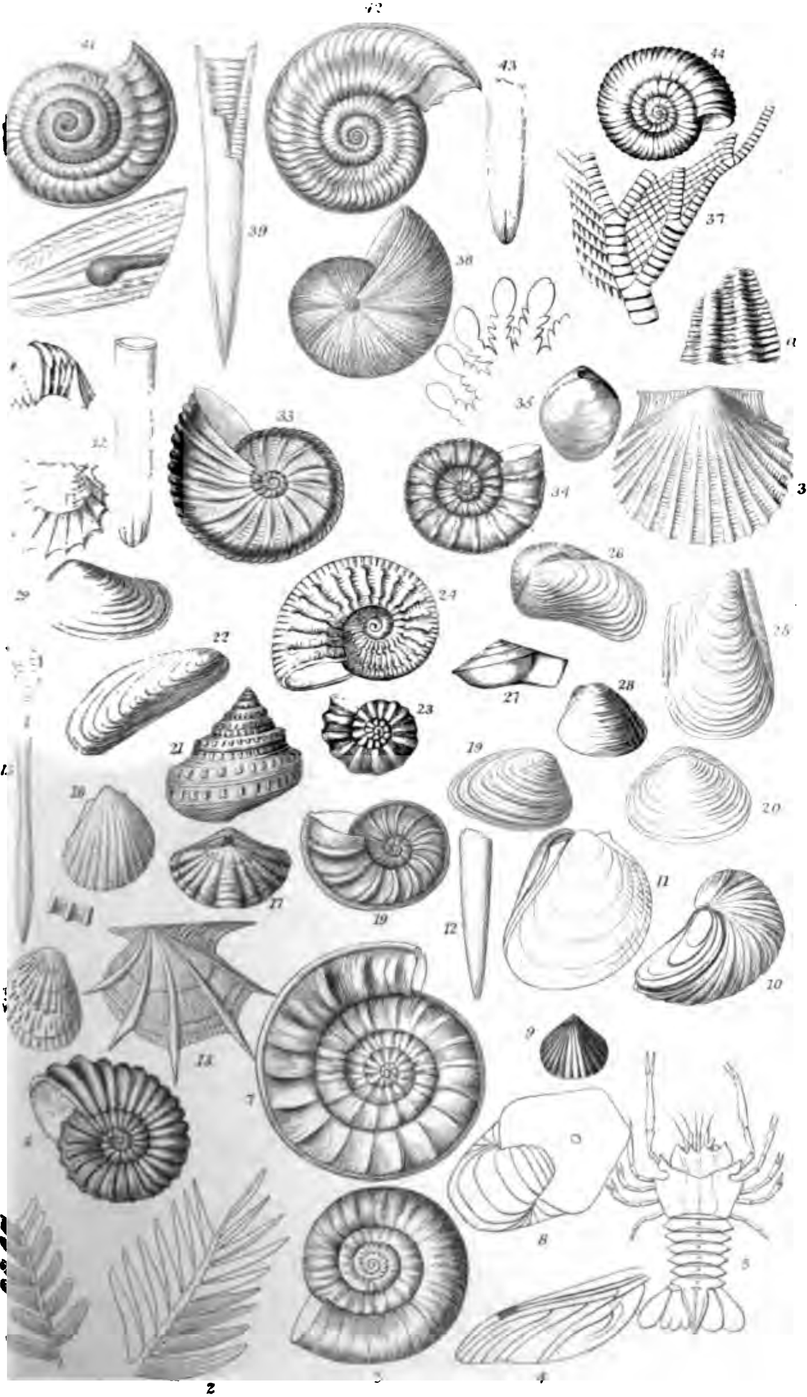
REFERENCE TO PLATE VIII, REPRESENTING FOSSILS OF THE LIAS.

L. Lower lias. M. Marlstone. U. Upper lias.

1. Palæozamia obtusa. *Lindley.* L. Axminster.
2. ,, Bucklandi. *Brong.* L. Bidford.
3. Ammonites planorbis. *Sow.* L. Bidford.
4. Wing of Libellula liassina *Strickl.* L.
5. Eryon Barrovensis. *M'Coy.* L. Bidford.
6. Ammonites angulatus. *Schl.* L. Southam.
7. ,, Bucklandi. *Sow.* L. Keynsham.
8. Nautilus truncatus. *Sow.* L. Deddington.
9. Rhynchonella variabilis. *Schl.* L. Southam.
10. Gryphæa incurva. *Sow.* L. Southam.
11. Lima gigantea. *Sow.* L. Southam.
12. Belemnites acutus. *Blainv.* L. Fenny-Compton.
13. Avicula cygnipes. *Phil.* L. Banbury, Horfield.
14. Plicatula spinosa. *Sow.* L. Fenny-Compton.
15. Belemnites clavatus. *Blainv.* L. Cheltenham.
16. Lima pectinoidea. *Phil.* L. Fenny-Compton.
17. Spirifera Walcotti. *Sow.* L. Fenny-Compton.
18. Ammonites obtusus. *Sow.* L. Cheltenham.
19. Cardinia Listeri. *Sow.* L. Cheltenham.
20. Unicardium cardioides. *Phil.* L. Banbury.
21. Trochus anglicus. *Sow.* L. Southam.
22. Modiola scalprum. *Sow.* L. Deddington.
23. Ammonites planicostatus. *Sow.* L. Cheltenham.
24. ,, Henleyi. *Sow.* L. Stow.
25. Crenatula ventricosa. *Sow.* L. Stow.
26. Hippopodium ponderosum. *Sow.* L. Fenny-Compton.
27. Pleurotomaria expansa. *Sow.* L. Banbury.
28. Cardium truncatum. *Sow.* M. Byfield.
29. Myacites donaciformis. *Phil.* M. Bredon.
30. Avicula novemcostæ. *Bronn.* L. and M. Fenny-Compton, Banbury.
31. Rhynchonella tetraëdra. *Sow.* M. Byfield.
32. Belemnites paxillosus. *Schl.* M. Byfield.
33. Ammonites margaritatus. *Montf.* M. Cheltenham.
34. ,, spinatus. *Brug.* M. Cheltenham.
35. Terebratula resupinata. *Sow.* M. Byfield.
36. Pecten æquivalvis. *Sow.* M. Byfield.
    a. portion of the surface.
37. Extracrinus caput medusæ (?). *Miller.* U. Banbury.
38. Ammonites heterophyllus. *Sow.* U. Rowsham.
39. Belemnites elongatus. *Sow.* U. Rowsham.
40. Dorsal plate of Geoteuthis with 'ink-bag.' U. Alderton.
41. Ammonites bifrons. *Brug.* U. Rowsham.
42. ,, serpentinus. *D'Orb.* U. Cheltenham.
43. Belemnites irregularis. *Schl.* U. Cheltenham.
44. Ammonites communis. *Sow.* U. Rowsham.

Pl. VIII.

LIAS



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CHAPTER XI.

THE BATH OOLITE PERIOD.

THROUGHOUT England the upper limit of this large group of rocks is very well marked by the highest bed, 'Cornbrash,' under the Oxford clay, which is continuous across the country north of Oxford. The lower limit is not so firmly settled, because the 'Inferior oolite,' which marks the boundary, is far from being so continuous or so uniform in composition or contents as the cornbrash.

The strata composing the group were all fully studied and named by Smith in the latter part of the last century, near Bath. His series stands thus [a] :—

Cornbrash.
Sand and sandstone (of Hinton).
Forest marble (of Farleigh Castle).
Clay over the Upper oolite (Bradford).
Great or Upper oolite.
Fuller's-earth and rock.
Inferior oolite.
(Sand. Also classed with lias.)

And it remains without alteration.

In a general point of view, the whole is a succession of limestones, oolitic or shelly, laminated or massive, alternating with clays and sands locally hardened to sandstones.

In the following Tabular View the proportions of the several component beds appear as they may be seen about Cirencester and Cheltenham. Some of the more characteristic fossils are mentioned opposite the parts of the section where they are found to prevail.

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[a] 'Geological Table of British Organized Fossils,' in 'Stratigraphical System.' 4to. London. 1817.

In some cases these are confined to very narrow limits, and are really characteristic of definite geological epochs[b]. Under two principal groups several subdivisions are included; but the Fuller's-earth zone is kept separate, on account of its argillaceous character. The sands and cephalopoda bed are included for convenience of study.

Oxford Clay above.

Avicula echinata.		Cornbrash.	Nucl. orbicularis.
Nucula lachryma. Terebr. maxillata.	Great Oolite.	Upper or Forest marble.	
		Middle or Great oolite.	
		Lower or Stonesfield.	Hemicidaris Stokesii.
Ostrea acuminata.		Fuller's-earth.	
Trigonia costata. Rhynch. spinosa. Terebr. Phillipsii. Lima Etheridgii.	Inferior Oolite.	Ragstone.	Clypeus Plotii. Amm. Parkinsoni. Amm. Humphreysianus. Amm. Sowerbii.
		Upper freestone.	
Terebr. fimbria. Lucina Wrightii.		Oolitic marl.	Stomechinus germinans.
		Lower freestone.	Pygaster semisulcatus. Pseudo-diadema depressum.
		Pea-grit.	Amm. Murchisonæ.
Rhynchonella cynocephala.		Cephalopoda bed.	
		Sands.	Amm. opalinus.

Lias clays below.

Proceeding eastward from Cheltenham toward Oxford, as the sections in Plate IV. shew, the whole of this series, as well as the upper parts of the lias, grows thinner, so that in the country about

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[b] See also the sections in Plate IV. and Plate V.

Burford, and about Stonesfield, the whole thickness is but one-fourth of that near Cheltenham. This arises from the great reduction of the Inferior oolite, from two or three hundred feet to less than twenty, and from the absence or extreme attenuation of the fuller's-earth[c].

Thus, on the side of the Evenlode valley, we have about 100 feet of strata, viz.:—

Cornbrash	8 to 10 feet.
Forest marble with accompanying clays	20 to 30 feet.
Great oolite—white marly flaggy and sandy	40 to 60 feet.
(Occasional clay bed.)	
Inferior oolite	10 to 20 feet.

The lower part of the Great oolite is the famous bed of Stonesfield slate.

Now passing north-eastward to the valley of the Cherwell, we find about Steeple-Aston and Deddington a similar series, with the addition of a band of ironstone at the bottom, but no true Inferior oolite.

The series reads thus:—

Cornbrash	8 to 10 feet.
Forest marble	20 to 30 feet.
Great oolite—white marly flaggy and sandy	50 feet.
(Occasional clay bed.)	
Ironstone band	1 to 8 feet.

The facts thus collected agree with the opinion unanimously adopted by the National Survey in their maps and sections, viz. that the true Inferior oolite is extinct in the region north of Oxford, as well as the fuller's-earth beds. The iron-bands, however, at the base of the whole series, have come by degrees to be recognized as coeval with those which are the lowest beds of the Inferior oolite series of Northamptonshire, Lincolnshire, and Yorkshire. This can hardly be doubted as we proceed in our examination eastward and north-eastward.

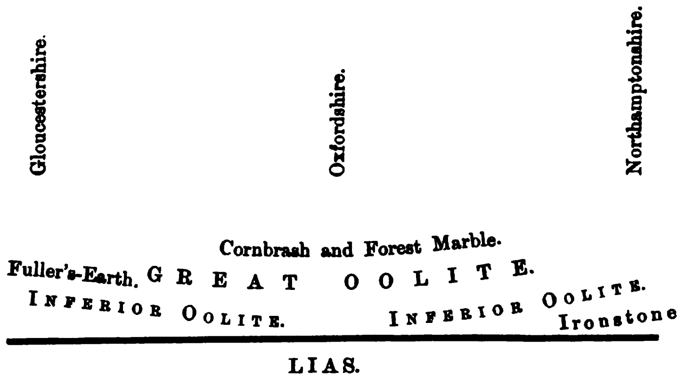
[c] The clay bed often recognized above the iron bands and sands associated with them, and sometimes observed below the Stonesfield slate, may be regarded as the continuation or representative of the fuller's-earth.

Crossing over to the drainage of the Nene, and still proceeding north-eastward, we find the series enlarged and thickened in parts, viz.:—

Cornbrash	8 or 10 feet.
Forest marble and clays	5 to 10 feet.
White oolite	20 or 30 feet.
Blue clay	15 feet.
Variable sands, white, grey, and yellow	10 to 20 feet.
(Occasional and variable limestones)	20 to 30 feet.
Ironstone	10 to 30 feet.

In the country north-east of Northampton we find these strata continued; and in addition, it is believed by Mr. Sharp, toward the lower part of the series, probably above the variable sandy zone, a thick bed of oolitic limestone comes in, which may perhaps with confidence be referred to the upper or middle portion of the Inferior oolite of Cheltenham. This oolite is continued into Lincolnshire, with great part of the superincumbent beds.

Regarded in a general manner, then, the Bath oolite series, in its course eastward from Cheltenham to Stamford, may be represented in a sectional Diagram, as above; wherein the fuller's-earth is found in thickness to die out eastward, and the Inferior oolite first to be contracted to almost a line above the lias, and then to be expanded again in two or three parts, the lowest being an ironstone band.



The subdivisions of this great oolitic mass are not yet fully traced out; and till it is done, the further extension of the classification into Yorkshire must be in some degree doubtful.

We may now take up the several strata in succession.

INFERIOR OOLITE GROUP.

The most complete sections of the Inferior oolite which are easily accessible from Oxford are in the noble hills above Cheltenham. In 1834, Sir R. I. Murchison produced an Outline of the Geology of Cheltenham, in which the section is given in considerable detail, the Inferior oolite being considered in three divisions, thus placed:—

Gryphite grit, coarse and very fossiliferous.
Oolite freestone, much quarried, with fewer fossils.
Pea-grit, with distinct concretionary masses of small size.

Of these the middle division is much the thickest, and contains several distinguishable layers, as—

d. Cream-coloured marlstone.
c. Upper ragstone.
b. Freestone.
a. Lower ragstone.

A considerable list of the fossils is given in this short but useful memoir.

In 1843, Mr. Buckman published a geological chart of the oolitic strata of the Cotteswold Hills and the lias of the Vale of Gloucester, in which the sections of these strata and their embedded fossils are more fully detailed. The same author contributed with Mr. Strickland to augment the second edition of Murchison's Outline with many important additions. Mr. Brodie has laboured successfully in this field. Finally, Dr. Wright, after re-examining the elevated escarpments of Leckhampton and Cleeve-Cloud, has arrived at an almost complete view of the subdivisions of this fine oolitic series[d]; and Mr. Hull's memoir on the same district, to accompany the maps of the Geological Survey, completes this valuable series of works.

Mr. Hull's general section, founded on actual measures, assigns no less than 264 feet[e] to the Inferior oolite near Cheltenham. The whole series in the hill is thus expressed:—

[d] Palæontographical Society, vol. for 1861, issued 1863.

[e] This is the sum of the thicknesses as given in the section; in the text the statement is 236 feet.

Inferior oolite	e. Ragstone	38 feet thick.
	d. Upper freestone	34[f] ,,
	c. Oolitic marl	7 ,,
	b. Lower freestone	147[g] ,,
	a. Pea-grit	38 ,,
Upper lias	Cephalopoda bed	8 ,,
	Sands	20 ,,
	Blue shale	202 ,,
Middle lias	Marlstone	115 ,,
Lower lias probably exceeding		500 ,,

The reader may now turn to the vertical sections given in Plate V, for an example of the rapid thinning, towards the south-east (from Gloucestershire to Oxfordshire), of all these strata—the Inferior oolite, in fact, almost disappears. The same thing appears in the longitudinal sections in Plate IV, from Cleeve and Broadway towards Oxford.

The Pea-grit, the lowest of the five divisions of Mr. Hull, derives its name from the character of its substance; for it is composed mainly of flattened spheroidal masses of the size of peas. It is a very large grained oolite—a pisolite—each mass enclosing an organic fragment which served for a point of concentric attraction to the concreting mass of carbonate of lime. But some of the spheroids appear to be merely worn fragments. This curious 'basement bed' is of only limited extent, to the south and north of Cheltenham. It is specially rich in corals, echinida, and crinoids, none of which occur in the cephalopoda bed below, while, unlike that bed, it contains but few ammonites, nautili, and belemnites. Other mollusca are plentiful in the pea-grit. The lower part, which contains much iron oxide interposed among oolitic grains, is treated as a separate member by Dr. Wright in his notice of Cleeve-Cloud Hill[h].

The Lower Freestone of Mr. Hull has furnished immense supplies of valuable building stone, from Painswick to Cleeve and Broadway, and from Bourton-on-the-Hill to Naunton and Guiting. The buildings constructed of it are durable, the stone hardening by exposure from a state of softness, when taken from the quarry, which allows of separation by the toothed saw. The texture is oolitic; there are many small fragments in the mass, especially parts of echinodermata, and it yields a large series of other fossils, especially

[f] 28 feet in the text.

[g] 127 feet in the text.

[h] Presented to the Cotswold Club, 1865.

mollusca. From 127 (or 147) feet of thickness in Leckhampton Hill, this massive freestone diminishes to about 40 or 46 at Turkdean near Naunton; at Sherborne it is reduced to 5 feet; and at Stow, Rissington, and Burford it entirely disappears[1].

As a building stone, the Inferior oolite nowhere acquires such importance, in respect of abundance or quality, as in the range of the Cotswolds of Gloucestershire, by Painswick, Leckhampton, and Broadway, and a tract of country extending south-eastward as far as Naunton. Within this large area it is everywhere productive of good freestone in great plenty, both of the fine-grained pure oolite, equal to Bath stone for ornamental structures, and of the stronger, partly shelly texture, which makes firm arch-stones, coping, sills, troughs, slabs, and steps. Near Cheltenham two bands of the 'freestone' are specially noted, the lower one very thick and largely quarried in Leckhampton Hill, in a range distinct from the other, which is also quarried near the summit. The Painswick oolite is often remarkably even in its spherical grains. Beyond the district named these freestones are of small importance or even absent, while the rougher beds at the top and bottom, the ragstone and pea-grits, are more continuously traceable. Near Bath the Inferior oolite yields but little, and that rarely any good freestone.

The ragstone is very often burned to lime, and both it and the pea-grit yield fair material for walling and road-making. The action of the weather, by means of rain, frost, and carbonic acid, is very obvious in these and other calcareous rocks. Thus are the beds broken up into small fragments, the natural joints widened, and their sides penetrated; the surfaces of the rocks pitted and undulated, so as to produce in exposed situations very fantastic hollows, branching ridges, and crests—the Daglingworth stones are an example in the Great oolite, which often shelter shell-snails, and sometimes suggest the idea of these animals having made the holes into which they retire.

The surface of some hard beds has been bored by lithodomous mollusks, making cylindrical holes; an important fact, shewing the slowness of the deposition of these rocks, one bed having acquired solidity and remained exposed to the ravages of oceanic residents before the commencement of the formation of that which succeeds.

---

[1] Hull in Memoirs of Geological Survey, 1857.

These appearances are not infrequent in beds near the top of the ragstone series, as about Broadway Hill, above Andover's Ford, near Pewsdown, and Northleach.

Oolite marl.—This layer, though seldom more than seven feet in thickness, extends over the whole space from Leckhampton to Cleeve-Cloud, Broadway, and Bourton-on-the-Hill, and everywhere yields abundance of one fossil, Terebratula fimbria, which is hardly known elsewhere. What is a little remarkable, Terebratula maxillata (a shell common in the upper beds of the Great oolite) is found in this marl in the district near Cheltenham. A good locality for this marl is in descending the hill on the road from Wisley Hill to Seven Springs. Dr. Wright regards the oolitic marl as a disturbed portion of a coral bed in the oolitic sea—a sort of aggregated 'coral-mud.'

Upper Freestone.—A thick-bedded oolite, of coarse texture; occasionally traversed by veins of fibrous iron oxide (hæmatite), and more frequently stained yellow by diffused iron carbonate. This stone is quarried largely at Broadway and Stanway, yielding large and excellent troughs, slabs, coping, etc. But few fossils in it: Terebratula fimbria is mentioned by Wright.

Ragstone.—This is a series of rough shelly sandy limestone, with layers of marl and sandstone, in which, especially about the upper part, are many trigoniæ, limæ, gryphites, terebratulæ, trichites, etc. The uppermost surface is occasionally bored by lithodomi; and the same fact is noticed in the lowest hard bed—about Bourton, Naunton, and Birdlip. In several districts, especially about Colesbourn, Stow, Churchill, Ascott, and Burford, the ragstone is represented by a white rubbly oolite, uncommonly full of Clypeus Plotii; and this only a few feet thick, as we go south-eastward, is all that remains of the thick Inferior oolite of Cheltenham. The fossils vanish in the same proportion, so that in the lower part of the Vale of the Cherwell hardly any record of the older life of the oolitic period remains, beyond a few species of wide range or doubtful identity.

Still it is to be observed that almost everywhere in the large region between Evenlode and Cherwell traces, more or less clear, of the Inferior oolite period present themselves.

About Charlbury beds of white oolite or ragstone lie on the upper lias, thus described in my note-book, 1855:—

Rubble and shelly oolite with Ostrea crassa, Pholadomya, &c. (elsewhere Trigonia).
Rubble or concretionary pisolitic bed.
Rough gritty bed, resting on upper lias.

These are subjacent to slaty beds of the Stonesfield series.

Passing toward the Cherwell, in the country round Deddington, we find the lias capped by irony and sandy bands instead of oolite.

The following notes on the strata at Worton, written in 1854, will serve as an index for this peculiar series in a large part of the area between the Evenlode and the Cherwell.

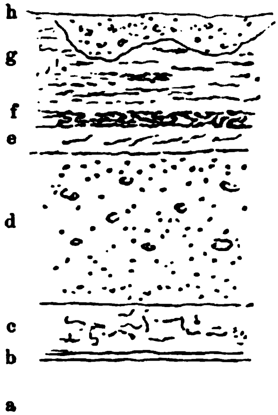


Diagram XXVII. Strata at Worton.

h. Soil, with pebbles of the northern drift.
g. 'Pale plank beds,' sandy and shelly layers. Four feet. (Rhynchonella, Ostrea, Ceromya.)
f. Chocolate-coloured iron ore, twisted and in concentric masses, half a foot; some oolitic grains : this is a rich ore.
e. Pale stony bands with plants. One foot.
d. Pale sands with dispersed masses of poor shelly iron ore, five and a half feet.
c. Limestone. Two feet.
In the series c to f occur Myacites, Lucina, Pholadomya, Pleurotomaria, Nautilus lineatus, Belemnites giganteus.
b. Red clay, a mere parting with water.
a. Upper lias clay. Thirty or forty feet.

At Stow-Nine-Churches, near Weedon-Beck, the series of strata belonging to the Bath oolite period was thus observed (1870):—

Great oolite of various kinds, white or ferruginous in places, especially near the top. *Fossils in plenty*, including Clypeus Plotii . . 30 feet.
The base not clearly seen.

(Interval, probably blue clay.)	
Yellow and white sand and sandstone, plants	15 feet
Brown ferruginous sandstone	15 ,,
Ironstone of good quality	12 ,,
Below is Upper lias clay.	

The interval, above mentioned, is occasioned by a fault which has traversed all these strata. Very few fossils occur in the sands or in the ironstone at this place.

FULLER'S-EARTH ZONE. (*Smith.*)

In the country round Bath the two principal masses of oolitic rock are separated by a considerable body of calcareo-argillaceous marls and clays with imbedded strata of stone, often soft, less frequently compact and solid, rarely oolitic. The thickness of these beds near Bath is found to be as much as 150 feet; but as we proceed northward, the fuller's-earth series grows thinner continually, and finally dies out in the valley of the Windrush, about Barrington; so that in the country round Burford, the two oolites referred to are no longer separated by this argillaceous band, but are brought into contact[k].

In other places, as at Stonesfield, blue clay of small thickness is seen, and may be regarded as a feeble equivalent of the fuller's-earth group. Through a great proportion of its range the fuller's-earth zone yields fossils much allied on the whole to those of the Inferior oolite below, and in a less degree to those of the Great oolite above. They are not distinctive, unless the remarkable prevalence of Ostrea acuminata in their bands can be so regarded. Belemnites and ammonites are rarely seen in it; yet one canaliculated species is recorded near Bath by Smith in his 'Stratigraphical System,' and again in Dorsetshire by Mr. Buckman. Rhynchonella media of Sowerby (R. varians, *Dav.*) is prevalent near Bath, but not in Gloucestershire.

GREAT OOLITE GROUP.

Three portions may be distinguished in the Great oolite of Gloucestershire and Oxfordshire, viz.:—

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[k] Lonsdale Geol. Soc. Proc., i. 414. Hull, in Memoirs of Geol. Survey, Sheet 44. 1857.

Upper Division, composed of clays and shelly limestones, more or less oolitic, to which the names of *Cornbrash, Forest marble, and Bradford clay* were applied by Smith.

Middle Division, composed of compact shelly or oolitic limestone, in beds of various thickness, with marly or argillaceous partings.

Lower Division. Thin-bedded limestones associated with sands, 'Stonesfield slate,' or laminated 'ragstone.'

THE LOWER DIVISION OF THE GREAT OOLITE.

'*The Stonesfield Beds.*'

This range of variable strata, oolitic, arenaceous, and ferruginous, corresponds to the 'lower rags,' a rather indistinct part of the great oolitic system in the south-west of England; it becomes conspicuous near Wotton-under-Edge, passes across the Cotswold Hills, and traverses Gloucestershire and Oxfordshire.

High in the hills near Wotton-under-Edge it is plainly to be recognized as a laminated rock, lying over the thick marly strata, which are the 'fuller's-earth and fuller's-earth rock' of W. Smith. False-bedding is very common in this rock over extensive tracts, a mark of currents in shallow water. It is often sandy and calcareous; fissile by art, and by exposure to atmospheric agencies. It contains Trigonia impressa, but is not rich in fossils till we reach the country between Cheltenham and Burford.

In this line at Sevenhampton, near Cheltenham, and Eyeford, near Stow, are many extensive quarries where this stone is dug for roofing, and is called 'slate.' The succession of strata in general terms may be thus expressed[1]: the lower portions, a and b, being regarded as 'Stonesfield beds,' and c as parting them from the ordinary Great oolite:—

		ft.	in.
c	Shelly clay—Rhynchonellæ	6	0
	Thin layers of shelly oolite	0	8
	(In these upper strata Ostrea acuminata occurs.)		
	Sandy marl and a few shells (sometimes absent)	8	0
b	Ragstone, a hard oolite, in thin beds, with blue centres—shells, plants, fish-teeth, one ammonite	14	0
a	Slate, sandy, laminated, with few shells, one ammonite	4	0
	(Clay appears beneath.)		

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[1] Brodie on Fossil Insects, p. 41.

In the Windrush quarries near Burford Mr. Lonsdale[m] observed:—

		ft.	in.
d	Rubbly limestone	1	0
	Brownish marlstone	6	0
	Rubbly limestone	4	0
c	Pale sandy marl	3	0
	Rubbly limestone	0	6
	Light coloured clay	0	6
b	Rag and freestone	15	0
a	Sandy laminated stone	variable.	

On comparing these sections we observe special differences in the upper part, but a considerable agreement in the lower part.

Dr. Fitton obtained the following account of the strata at Stonesfield[n]:—

d	Rubbly limestone		32	0
	Clay with Terebratulites			
	Limestone			
	Blue clay			
	Oolite			
c	Blue clay			
b	'Rag,' consisting of shelly oolite, with casts of bivalves and univalves, about		25	0
a	The slate beds, consisting of	'Soft stuff,' 6 in., yellowish sandy clay, with thin courses of fibrous transparent gypsum.		
		'Upper head,' 1 ft. 3 in. to 1 ft. 6 in., sand enveloping a course of spheroidal laminated calcareous gritstones, which produce the slate. These are called 'Potlids,' from their figure, and receive with the other slaty bed the name of 'Pendle,' as characteristic of the workable stone. The stone is partially oolitic and shelly, sometimes full of small fragmentary masses.		
		'Manure,' or 'Race,' 1 ft., slaty friable grit rock.		
	The slate beds, consisting of	'Lower head,' 1 ft. 6 in. to 2 ft., sand and grit, including a course of spheroidal concretions of slate, as above.		
		'Bottom stuff,' 1 ft., sandy and calcareous grit, with admixtures of oolitic grains.		

The floor of the slate beds is 'rag,' like the oolite above.

In the railway cutting near Stonesfield are several instructive sections. Where the road crosses by a high viaduct we have the following series of beds:—

[m] Proceedings of Geol. Soc. i. 414.

[n] Zool. Journal, vol. iii.

		ft.	in.
d	Soft marly bed	5	0
	Hard stone	1	6
	Soft marly bed	5	0
	Hard stone	2	0
	Soft marly bed	5	0
	Solid stone	3	0
	Soft marly bed	5	0
c	Laminated beds	2	6
b	Rag oolite	12	0
a	Slaty rag	5	0

Some of the beds here described as marly may very probably appear more argillaceous in the pits at Stonesfield, and indeed they are so at another part of this cutting.

The letters a, b, c, d, added to these sections, shew the general conformity of all, the rag and slate series lying apparently in the most continuous strata.

Proceeding northward to the drainage of the Glyme, we find about Sandford, in place of the 'Stonesfield slate,' beds of white and yellow sand, sixteen or more feet in thickness, with irregular laminæ of calcareous sandstone, more or less blue in the centre, called 'plank.' This is sometimes covered by six feet of clay, which is employed for making bricks. Clay appears below, which is regarded as of the upper lias.

At Worton, between Steeple-Aston and Banbury, the lowest beds of the oolite series were found to consist of—

	ft.	in.
Small shells and sand, resting on limited patches of calcareous flagstone ('plank'), or when these were absent, on iron ore[o]	4	0

Above Rowsham, the lias is covered by thirteen feet of brown ferruginous sands, and sandstone with calcareous and irony layers; marly clay lies above, and then oolite of the rag character; followed by white oolite, crowning the hill at Hopcroft's Holt. These sands become more ferruginous and stony at Steeple-Aston, and have there been quarried to the extent of eight feet in thickness, but without success, for iron ore. They rest upon upper lias, as that does upon ferruginous marlstone.

On reviewing these sections we find no reason to doubt that the Stonesfield beds are justly co-ordinated on the one hand with the thin-bedded rocks at the base of the Great oolite of Gloucestershire, and on the other, with the sandy and calcareous deposits lying above the iron ores which rest on the lias of Oxfordshire. Whether they are continued, or in what way represented in Northamptonshire and Lincolnshire, may be considered at the end of this chapter.

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[o] Phillips in Geol. Soc. Journal, 1859.

MIDDLE DIVISION OF THE GREAT OOLITE.

By those who live under the shadow of Combe Down and the other hills near Bath, the title of Great oolite will be readily conceded to the thick rock which crowns those elevations with a wreath of valuable freestone. From quarries in this rock Bath and many towns and cities have been built; and it preserves its importance and superiority, as compared with the other members of the system, till, as we go northward, we reach the vicinity of Gloucester and Stroud. Here, as already stated, the thick rocks of Painswick and Leckhampton, which belong to the Inferior oolite, become the most prolific centres of valuable freestone. The Great oolite, however, continues to be a considerable member of the series, as we proceed by Thames-head and Cirencester, Northleach and Burford, Shipton and Chadlington, Stonesfield and Enslow Bridge. Along both sides of the Cherwell it maintains a considerable thickness, stretching to the northward, toward Deddington and Aynhoe, and turns off by Brackley and Buckingham to Blisworth and Northampton. After leaving the downs over Bath, we find the thickness of the Great oolite to diminish northwards. From 105 feet, near Bath, it sinks to 60 in Gloucestershire and Oxfordshire, and to 30 feet in Northamptonshire. These measures are independent of the variable series above, known as Forest marble and Bradford clay.

The composition and structure of the rock are inconstant; when purely oolitic, with few or no shells, it is usually massive and good freestone. When shells become plentiful and range themselves in layers (sometimes oblique), the stone becomes more fit for rough walling and strong foundations than house-building. This kind of 'ragstone' is like forest marble, and often is not easily distinguished from that rock. In Oxfordshire usually the beds of stone are more or less separated, especially in the upper parts, by thinner bands of marly clay, which appear to have been derived from the same source and to indicate operations of the same kind as the clays of the forest marble above. Those clays are frequently estuarine, but these in the oolite proper seem to be more truly marine.

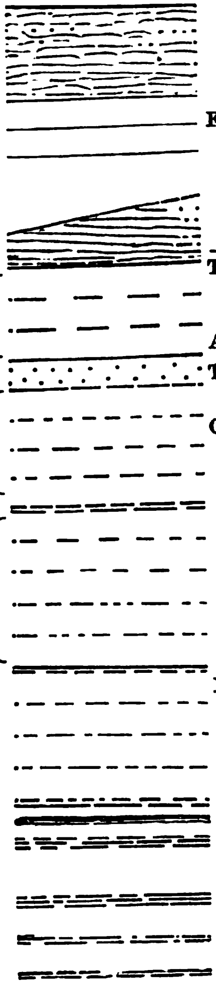
In the vicinity of Burford this rock yields abundance of good freestone. In particular, the vast and ancient quarries of Taynton furnish building-stone of the best and firmest description; not so fine-grained as that of Bath, but of superior durability. For ordinary walling, road-making and lime-burning, the rock is opened at frequent intervals in its course from Thames-head and the vicinity of Cirencester, by Northleach, Burford, Taynton, Shipton, Chipping-Norton, Woodstock, Enslow Bridge, and Brackley, to Buckingham.

The railway cuttings near Northleigh and Stonesfield exhibit a considerable variety of structure and texture in the beds of oolite, and in the marly and argillaceous partings. There are for short distances bands of coral and nests of nerinæa, and other shells, but rarely any approach to 'coral-reef' or extended shell-bed.

On a general view the Great oolite of Oxfordshire is much different from the coeval type first studied near Bath. The difference is to be explained by unequal depth of sea, and unequal subjection to littoral currents and estuarine influence. In one respect, however, it is the agreement which strikes us, the agricultural similitude; the surface is equally dry and well suited for the plough and artificial crops. Under the soil the stone is usually much divided, both horizontally and vertically, by the effect of long atmospheric vicissitude; and the thin broken layers thus formed are often found disturbed and shaken about. Still lower this does not happen, but the open fissures continue, and allow of the percolation of heavy showers, which leave white traces of their passage in delicate and abundant deposits of lac lunæ, and rarer deposits of stalagmite.

At Enslow Bridge and Kirtlington Station, quarries in the oolite exhibit most of the beds in relation to the forest marble and cornbrash above, and the Stonesfield beds beneath. The large old quarry opened on the west side of the Cherwell at Enslow Bridge, which has yielded a vast quantity of stone for walling, roads, and lime, presents the following succession of beds below the cornbrash :—

CORNBRASH.



feet.		
5 to 6.	Clay and thin stone .	
2.	Rough stone . .	Forest marble and clays.
2.	Clay and stone . .	
3 to 6.	Rough oolite . .	
2 to 4.	Clay	
6.	Oolite, white and partly compact, three or four beds . . .	Top ferruginous, often covered by oysters, and drilled by Lithodomi. Arca, Cardium.
2 to 3.	Terebratula bed . .	Terebratula maxillata.
8.	Four beds of white oolite . . .	Cardium, Lucina.
	Clay	
10.	Five beds of white oolite . . .	
	Sandy?	
14.	Eight beds of white oolite, with clay partings . . Clay Clay Clay	Nautilus, Tereb. fimbria, T. maxillata, Pecten arcuatus, Lima cardiiformis, Pholad.Heraultii, Rhynch. obsoleta, Nucleol. clunicularis, Clyp. Plotii, Isastræa.
16.	Several beds of oolite and clay . . .	

Several of these oolitic beds occasionally become marl in this and other quarries. Beneath is a marly and sandy series, the supposed equivalent of Stonesfield beds.

UPPER DIVISION OF THE GREAT OOLITE GROUP.

Bradford Clay and Forest Marble.

The great mass of oolite in the vicinity of Bath is covered by pale blue clays and thin beds of shelly rock. The former is named Bradford Clay, from the place in Wiltshire where it was most known and best exhibited; the latter is called Forest Marble, from the Forest of Wychwood, where it was first observed by Smith. Taken together, they constitute a variable zone of separation between the Cornbrash and Great oolite, as these terms are commonly understood; variable in total and relative thickness, in structure, and in original circumstances of deposition. They appear to be most frequently marine deposits; but in many cases, drifted oysters and fragments of wood, and in a few examples Cyrenæ, indicate estuarine fluctuations and inflowing fluviatile currents.

The shelly beds are sometimes compact enough to deserve the title of a rude marble, which may still be seen in ancient farm and manor houses, but it is not now anywhere polished on a large scale. These beds are very irregular, and even within short distances vary greatly in thickness (as at Islip and Kirtlington Station), and admit of much variety in the direction of bedding, from horizontal and parallel to the usual inclination of steep shell drift (30° or 40° from the horizon), and this in different directions.

The clays are not traceable continuously; they are considerable about Cirencester and Fairford, and are observed as white, partly indurated marl, in the productive excavations of Islip, where Terebellaria ramosissima and Terebratula digona remind us of the Berfield pits at Bradford, but no Apiocrinites have as yet occurred in our Oxfordshire sections.

One of the most extensive and characteristic excavations in the Forest marble is at Poulton, between Fairford and Cirencester. Here quarries, worked for ages over a large space of ground, have yielded roofing-slate for most of the houses in Lechlade, Fairford, Cirencester, and the neighbouring parts of South Gloucestershire, as well as flags for pavement, and abundance of road materials. The strata lie with a southward slope, and occupy a considerable breadth, without any over-covering of cornbrash.

The largest quarry now in work was opened some forty years since, and the excavation extends over an acre of ground or more. The strata are thin, mostly alternating clays and shelly stone, to a depth of twenty feet. Undulations on a large scale in some groups of stony beds are terminated by a continuous plane surface of softer yellow or white marly clay. False-bedding also occurs under continuous plane shelly stone. The stone is blue in the depths, but embrowned or tinted yellow by exposure at the surface or along the joints. The surfaces are much and grandly rippled, usually shelly, and especially covered with Ostrea, Pecten, Lima, spines of Cidaris, fragments of Coral, Montlivaltia, Terebellaria, and wood, all more or less drifted. The slates for roofing are of small size; some of the flags extend unbroken to six or eight feet square.

One of the best sections known is at the Kirtlington Station on the Oxford and Birmingham Railway, which was thus recorded by myself in 1859.

CORNBRASH.

	ft.	in.	
Pale clays and interrupted thin laminæ of Forest marble, oolitic and full of shells and fragments	12	0	
Solid shelly bed, top oolitic, middle close-grained, base sandy	3	9	
Sandy and marly bed	0	6	
Dark laminated clay with jet . . .	0	10	Cyrena.
Pale blue clay with calcareous nodules .	0	8	
Dark clay with jet	0	8	
Pale blue clay	0	8	
Brown clay	0	9	
Sandy layer	0	6	
Oolite, waterworn, with attached and drifted oysters and terebratulæ . .	2	4	
Parting clay			
Oolite, usually compact	2	6	
Parting clay			
Bed full of Terebratula maxillata, the valves united	3	0	

If this section be compared with those copied by Morris in the Great Northern Railway cuttings of South Lincolnshire, the conformity of the groups will be evident. In both, clays of different tints, with stony layers, and shells of marine and estuarine character, with jet and other remains of plants, lie under the cornbrash, and above the principal masses of calcareous rocks, which appeared to Morris to be of the upper or Great oolite stage, both by continuity of range and organic contents[p].

UPPER DIVISION OF THE GREAT OOLITE.

Cornbrash.

In my early wanderings with the 'great discoverer' of the oolites, the thin rough shelly rock, which breaks up into 'brash' and makes good land for 'corn,' was always trusted as the upper limit of the Bath oolite series; and the continuity of a deposit rarely exceeding eight feet in thickness, across England from Devonshire to Yorkshire, was a theme of frequent contemplation.

Only partially oolitic, rarely of much local utility except for walling and road-making, it is yet very frequently exposed in shallow excavations and over broad dry cultivated lands, and in each case yields fossils in considerable abundance and variety, not much different in general aspect from those of the Great oolite below, and, like them, not usually yielding any belemnites or many ammonites.

On this account, as already observed, the fossils of the cornbrash may be well included in a general catalogue of the fossils of the upper and middle division of the Great oolite series.

FOSSILS OF THE BATH OOLITE SERIES.

The organic remains in the oolitic system, taken generally, constitute one of the most complete records of the inhabitants of land and sea which can be referred to in the whole series of ancient life. Land plants, insects, reptiles, and mammalia; lacustrine and estuary shells, fishes, and reptiles; marine corals, echinodermata, annellida, crustacea, bivalve, univalve, and cephalopodal shells, fishes, and reptiles.

A remarkable uniformity runs through the whole system: thus cycadaceous and zamioid plants occur in the lower and upper strata; isastræa and montlivaltiæ, trigoniæ and pholadomyæ, nerineæ and pleurotomariæ occupy many of the rocks; plesiosauri, teleosauri, megalosauri, and ichthyosauri are familiar fossils in almost all stages of the oolites.

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[p] Geological Proceedings, 1853, p. 317.

Confining our attention at present to the lower of the three great groups, that of the Bath oolites, we find the most abundant zones of marine life to be collected about the base and the top of the two great masses of calcareous rock—the inferior and the great oolite. The principal repository of fossil, mostly land, plants is at the base of the great oolite in Oxfordshire, and toward the base of the inferior oolite in Northamptonshire. Corals, more or less presenting the aspect of a shelly reef, occur near the base of the inferior oolite, as near Cheltenham, and at the top of the great oolite, as at Castle-Combe in Wiltshire. The lists which follow are founded on one of the richest known districts, that of Gloucestershire; Oxfordshire having as yet yielded few species, and the Northampton fossils requiring separate enumeration in connection with Lincolnshire and Yorkshire. The Catalogue of fossils in the Museum of Practical Geology, Memoirs of Mr. Hull and other observers to accompany the sheets of the Geological Survey, Dr. Wright's essays in the Palæontographical Society's volumes, and in the Proceedings of the Cotteswold Club, have furnished ample information, and I have made diligent search myself. For the Northamptonshire fossils, believed to be of equal age, but found under different conditions of sea-bed, the latest memoir of Sharp (Geol. Proc. 1870) may be consulted. Morris, Brodie, and Ibbetson have examined the sections of Lincolnshire, and Mr. Judd is now revising the lower oolites, so as to complete the union between the section of Gloucestershire and that of Yorkshire.

The first Catalogue includes fossils of the inferior oolite from Gloucestershire, and chiefly from the vicinity of Cheltenham. An asterisk is prefixed to the names of species which have been also found in Northamptonshire. The different parts of the rock in which the fossils occur are marked by the letters

R. for the Rag beds and upper part of the rock.
F. for the Freestone beds in the middle.
P. for the Pea-grit and other lower beds.

FOSSILS OF THE INFERIOR OOLITE OF GLOUCESTERSHIRE.

PLANTS. Stems of coniferous wood in fragments.

ACTINOZOA. These are almost exclusively obtained from the lowest division—the Pea-grit beds—where they almost constitute a kind of dispersed reef.

Anabacia orbulites. *Lam.* *O. G. S.* R. Northleach.
Axosmilia Wrightii. *Edw.* R. Crickley.
Isastræa tenuistriata. *M'Coy.* P. Crickley.
Latomæandra cupuliformis. *Edw.* P. Crickley.
„ *Davidsoni. *Edw.* P. Crickley.
„ Flemingii. *Edw.* P. Crickley.
„ Waterhousii. *Edw.* P. Cleeve, Crickley.
„ Wrightii. *Edw.* P. Crickley.
Montlivaltia DelaBechii. *Edw.* P. Cleeve, Crickley.
„ trochoides. *Edw.* P. Winlay Hill.
Thamnastræa Defranciana. *Edw.* P. Crickley.
„ Mettensis. *Edw.* P. Crickley.
„ Terquemii. *Edw.* P. Cleeve, Crickley.
„ unguiformis. *Edw.* P. Crickley.
Thecosmilia gregarea. *M'Coy.* P. Crickley.

The corals here enumerated belong partly to genera already exhibited in the lias, and partly to others which continue through the following oolites.

FOSSILS OF THE INFERIOR OOLITE.

ECHINODERMATA.

Echinoidea.

Acrosalenia *Lycetti. *Wright.* P. Crickley. F. Leckhampton.
„ *spinosa. *Ag.* P. Crickley. F. Leckhampton.
Cidaris Bouchardii. *Wright.* P. Crickley.
„ *Fowleri. *Wright.* P. Crickley.
„ *Wrightii. *Desor.* P. Crickley.
Clypeus Plotii. *Leske.* R. Stow, Naunton, Burford, Cubberley, Cleeve, &c.
Pseudodiadema depressum. *Ag.* P. Crickley. F. Leckhampton. R. Colesburn.
Echinobrissus *clunicularis. *Lloyd.* R. Leckhampton, Northleach.
Hemipedina Bakeri. *Wright.* P. Crickley.
„ Bonei. *Wright.* P. Crickley.
„ perforata. *Wright.* P. Crickley.
„ tetragramma. *Wright.* P. Crickley.
„ Waterhousii. *Wright.* P. Crickley.
Holectypus depressus. *Lam.* R. Leckhampton, Andover's Ford.
Hyboclypus *agariciformis. *Forbes.* P. Cleeve, Crickley.
„ caudatus. *Wright.* P. Crickley. R. Leckhampton.
„ gibberulus. *Ag.* R. Leckhampton.
Pedina rotata. *Wright.* R. Leckhampton Hill, E. of Andover's Ford.
Polycyphus Deslongchampsii. *Wright.* P. Crickley.

Pygaster *semisulcatus. *Phil.* P. Cleeve, Crickley. F. Leckhampton.
Rhabdocidaris Wrightii. *Desor.* P. Crickley.
Stomechinus *germinans. *Phil.* P. Crickley.
„ perlatus. *Desor.* P. Crickley.

Crinoidea.
*Extracrinus. sp. P. Crickley.

These echinoïdea present a considerable addition of genera to those already named in the lias—especially Clypeus, Echinobrissus, Holectypus, Hyboclypus, and Pygaster—all belonging to the bilateral groups. Crinoïdea are fewer than in the lias, and asteroïdea appear to be hardly known.

FOSSILS OF THE INFERIOR OOLITE.

ANNELLIDA. Very few yet distinguished.
Serpula *socialis. *Goldf.* R. Fulbrook. F. Leckhampton.
„ lævigata. *M.* and *L.* F. Leckhampton.

CRUSTACEA. Slightly represented in the series.

POLYZOA. Insufficiently examined in the series.

BRACHIOPODA.
Rhynchonella *angulata. *Dav.* P. Cleeve, Crickley.
„ concinna. *Sow.* P. Cleeve, Crickley. F. Miserden, Sudeley, Cleeve.
„ Forbesii. *Dav.* P. Cleeve. R. Leckhampton, Andover's Ford, Sherborne, Stow.
„ Lycetti. *Dav.* F. Miserden, Sudeley, Cleeve, Stroud.
„ oolitica. *Dav.* P. Cleeve, Crickley.
„ *quadriplicata. *Zieten.* R. Cockbury.
„ spinosa. *Sow.* R. Andover's Ford, Burford, Fulbrook, Stroud.
„ subdecorata. *Dav.* P. Crickley.
„ *subtetraëdra. *Dav.* F. Miserden, Sudeley, Cleeve. R. Cockbury.
„ *tetraëdra. *Sow.* P. Crickley. F. Miserden, Sudeley, Cleeve.
„ varians. *Dav.* Near Andover's Ford.
Terebratula *Buckmanni. *Dav.* F. Leckhampton. R. Andover's Ford, Cleeve.
„ carinata. *Lam.* P. Cleeve. F. Miserden, Sudeley, Cleeve, Leckhampton. R. Stanley, Stowell.
„ cardium. *Lam.* Andover's Ford.
„ emarginata. *Sow.* F. Miserden, Sudeley, Cleeve.
„ Etheridgii. *Dav.* P. Winlay Hill.
„ fimbria. *Sow.* F. Leckhampton, above Seven Wells.
„ globata. *Sow.* F. Miserden, Sudeley, Cleeve. R. Leckhampton, &c.
„ *impressa. *Von B.* R. Leckhampton.
„ Lycetti. *Dav.* Westcombe, Gloucestershire.
„ maxillata. *Sow.* R. Leckhampton, Colesburn, Pinhill.
„ ornithocephala. *Sow.* R. Leckhampton, Cleeve.

Terebratula perovalis. *Sow.* P. Cleeve. F. Miserden, Sudeley. R. Leckhampton, Stanley, &c.
„ Phillipsii. *Dav.* R. Leckhampton, above Seven Wells, &c.
„ plicata. *Buckm.* P. Crickley. F. Miserden, Sudeley.
„ simplex. *Buckm.* P. Crickley.
„ sphæroidalis. *Sow.* Stinchcombe Hill.
„ *submaxillata. *Dav.* P. Crickley, Leckhampton. F. Miserden, Sudeley.
„ Waltonii. *Dav.* Cleeve.
„ Wrightii. *Dav.* R. Leckhampton.

The brachiopoda, though apparently reduced to rhynchonellæ and terebratulæ, are fully as numerous as in the lias, and are regarded for the most part as distinct species. Probably Discina and Lingula will be placed on record hereafter.

FOSSILS OF THE INFERIOR OOLITE.

MONOMYARIA.

Avicula complicata. *O. G. S.* Leckhampton.
„ costata. *Sow.* Cheltenham.
„ digitata. *Desl.* Stroud.
„ *inæquivalvis. *Sow.* P. Cleeve. R. Colesburn.
Gervillia *acuta. *Sow.* R. Stanley Hill.
„ costatula. *Desl.* F. Leckhampton.
„ Hartmanni. *Münst.* P. Cleeve. R. Sudeley, Cleeve.
„ lævigata. *M.* and *L.* F. Leckhampton.
Gryphæa Buckmanni. *Lycett.* R. Stroud, Leckhampton, Cleeve, Andover's Ford, Northleach, &c.
„ *subloba. *O. G. S.* Leckhampton.
Hinnites sepultus. *Lyc.* F. Leckhampton.
„ tuberculosus. *Goldf.* P. Crickley.
„ *velatus. *Goldf.* P. Crickley, Leckhampton.
Lima *cardiiformis. *M.* and *L.* F. Miserden, Sudeley, Cleeve.
„ duplicata. *Sow.* P. Crickley. R. Sudeley, Andover's Ford.
„ gibbosa. *Sow.* R. Leckhampton, Stow, Burford, &c.
„ *impressa. *M.* and *L.* P. Cleeve.
„ læviuscula. *Sow.* P. Crickley. F. Cheltenham.
„ lunularis. *Desh.* P. Crickley.
„ minutissima. *M.* and *L.* F. Leckhampton.
„ ovalis. *Sow.* P. Crickley. R. Leckhampton.
„ potata. *Goldf.* P. Crickley.
„ proboscidea. *Sow.* R. Leckhampton, Cleeve, Stowell, &c.
„ *punctata. *Sow.* P. Cleeve, Crickley. R. Sudeley, Cleeve.
„ punctatilla. *M.* and *L.* F. Leckhampton.
„ *rudis. *Sow.* R. Leckhampton, Sudeley.
„ semicircularis. Cheltenham.
„ squamicostata. *Bur.* F. Leckhampton.
„ sulcata. *Münst.* P. Crickley.

Ostrea acuminata. *Sow.* R. Stroud, Stowell, Naunton, Andover's Ford.
„ *costata. *Sow.* P. Crickley.
„ flabelloides. Cleeve.
„ *gregarea ? *Sow.* R. Leckhampton.
„ *Marshii. *Sow.* R. Stroud, Leckhampton, Stanley, Cleeve.
„ Sowerbii. Near Cheltenham.
Pecten ambiguus. *Münst.* R. Leckhampton.
„ annulatus. *Sow.* R. Leckhampton.
„ *arcuatus. *Sow.* R. Andover's Ford.
„ articulatus. *Schl.* P. Crickley.
„ clathratus. *Röm.* P. Crickley.
„ *demissus. *Phil.* R. Andover's Ford.
„ grandævus. *Goldf.* R. Leckhampton.
„ *lens. *Sow.* P. Crickley. R. Sudeley, Andover's Ford.
„ lineolatus. *M.* and *L.* F. Leckhampton, Turkdean.
„ *personatus. North-east of Cheltenham.
„ symmetricus. *M.* and *L.* R. Andover's Ford.
„ vagans. *Sow.* R. Andover's Ford.
„ vimineus ? *Sow.* R. Leckhampton.
Perna mytiloides. *Lam.* F. Leckhampton.
Pinna cuneata. *Bron.* P. Crickley.
„ lanceolata. *Sow.* Wotton-under-Edge.
Placuna Jurensis. *Röm.* P. Crickley.
Plicatula complicata. *Lyc.* P. Cleeve.
„ elongata. *Lyc.* P. Crickley.
„ *tuberculosa. *M.* and *L.* P. Cleeve.
„ ventricosa. *Goldf.* Cleeve.
Trichites nodosus. *M.* and *L.* P. Crickley. F. Leckhampton.

The generic agreement of this list of monomyaria with that already given for the lias is almost complete, the species being mostly different. Trichites now first appears.

FOSSILS OF THE INFERIOR OOLITE.

DIMYARIA.

Acromya. Cheltenham.
Arca lata. *Dunker.* F. Leckhampton.
„ pulchra. *Sow.* F. Leckhampton.
„ trisulcata. *Goldf.* F. Leckhampton.
Astarte *elegans. *Sow.* F. Near Cheltenham.
„ excavata. *Sow.* F. Leckhampton. R. Sudeley, Cockbury.
„ interlineata. *Lyc.* Leckhampton.
Cardium *Buckmanni. *Lyc.* F. Leckhampton.
„ *cognatum. *Phil.* F. Leckhampton. R. Andover's Ford.
„ cordiforme. *M.* and *L.* F. Leckhampton.
„ granulatum. *Lyc.* F. Leckhampton.
„ lævigatum. *Lyc.* F. Leckhampton.
„ puncto-striatum. *M.* and *L.* F. Leckhampton.

Cardium striatulum. *Sow.* R. Cockbury, Andover's Ford.
Ceromya *concentrica. *Sow.* P. Cleeve. R. Stroud, Leckhampton.
„ plicata. *Ag.* R. Stony-Cockbury.
„ Sarthensis. *D'Orb.* R. Stroud.
Corbis lævigatus. *M.* and *L.* F. Leckhampton.
Corbula depressa. *Phil.* F. Leckhampton.
„ Hulliana. *O. G. S.* Crickley.
„ imbricata. *M.* and *L.* F. Leckhampton.
„ involuta. *Goldf.* F. Leckhampton.
Cucullæa bipartita. *Lyc.* F. Leckhampton.
„ amœna. *Lyc.* F. Leckhampton.
„ *cancellata. *Goldf.* F. Leckhampton.
„ dense-granulata. *M.* and *L.* F. Leckhampton.
„ elongata. *Sow.* F. Leckhampton.
„ lævis. *Buck.* Cheltenham.
„ nana. *M.* and *L.* F. Leckhampton.
„ *ornata. *Buck.* Cheltenham.
Cypricardia cordiformis. *Desh.* R. Stroud.
Cyprina. A large species. R. Stony-Cockbury.
Dreissena lunularis. *M.* and *L.* F. Leckhampton.
Goniomya V. — scripta. *Sow.* R. Andover's Ford.
Gresslya latirostris. *G. S.* R. Leckhampton, Cleeve.
„ *peregrina. *Phil.* P. Cleeve. R. Stroud, Colesburn, Cleeve, Andover's Ford, Sherborne, &c.
Homomya crassiuscula. *M.* and *L.* R. Leckhampton.
Isocardia *cordata. *Buck.* R. Leckhampton.
„ rhomboidalis. *Phil.* R. Leckhampton.
Lithodomus attenuatus. *Lyc.* F. Leckhampton.
Lucina *Bellona. *D'Orb.* F. Leckhampton. R. Andover's Ford, Cleeve.
„ despecta. *Phil.* F. Leckhampton. R. Andover's Ford, Stowell.
„ lirata. *Phil.* F. Miserden, Cleeve, Sudeley.
„ *rotundata. *Röm.* R. Stanley.
Modiola cuneata. *Sow.* R. Stroud.
„ explanata. *Morris.* R. Stony-Cockbury.
„ furcata. *Goldf.* P. Cleeve. R. Stroud, Cockbury.
„ gibbosa. *Sow.* F. Miserden, Sudeley. R. Leckhampton. Fu. Cubberley.
„ *imbricata. *Sow.* R. Burford, Andover's Ford.
„ Jurensis. *Bronn.* R. Leckhampton.
„ plicata. *Sow.* P. Crickley. R. Leckhampton, &c.
„ tumida. *M.* and *L.* R. Cleeve.
Myacites calceiformis. *Phil.* R. Sudeley, Colesburn.
„ crassiusculus. *M.* and *L.* R. Stony-Cockbury.
„ decurtatus. *Phil.* P. Cleeve. R. Leckhampton, Cleeve, &c.
„ *dilatus. *Phil.* R. Stroud.
„ Jurassi. *Brong.* R. Andover's Ford.
„ oblongus. *Buck.* F. Leckhampton.
„ punctatus. *Buck.* P. Crickley. F. Leckhampton.
„ rotundatus. *Sow.* R. East of Andover's Ford.
„ securiformis. *Phil.* P. Cleeve.

Myacites tenuistriatus. *Ag.* R. Leckhampton, Cleeve, &c.
Myoconcha *crassa. *Sow.* R. Nailsworth. P. Crickley.
Mytilus crenatus. *M.* and *L.* F. Leckhampton,
  „ cuneatus. *Sow.* P. Crickley.
  „ pectinatus. *Sow.* P. Crickley.
  „ pulcher. *Goldf.* P. Crickley.
  „ striatulus. *Goldf.* P. Crickley.
  „ subrectus. *M.* and *L.* F. Leckhampton.
  „ sublævis. *Sow.* F. Near Cheltenham.
Nucula variabilis. *Sow.* F. Leckhampton.
Opis cordiformis. *O. G. S.* I. O. Rodborough.
  „ lunulatus. *O. G. S.* I. O. Leckhampton.
Pholadomya *ambigua. *Sow.* R. Sudeley, Cleeve, Andover's Ford, &c.
  „ *fidicula. *Sow.* P. Cleeve. R. Stroud, Stanley, Leckhampton.
  „ gibbosa. *Sow.* R. Leckhampton.
  „ *Heraultii. *O. G. S.* Leckhampton.
  „ lyrata. *Sow.* R. Leckhampton, &c.
  „ Murchisoni. *Sow.* R. Leckhampton, &c.
  „ ovalis. *Sow.* R. Leckhampton.
Ptychomya Agassizii. *M.* and *L.* F. Leckhampton.
  „ detrita. *Goldf.* F. Leckhampton.
Quenstedtia *lævigata. *Phil.* P. Crickley.
Sphæra Madridi. *D'Arch.* F. Leckhampton.
Tancredia curtansata. *Phil.* F. Leckhampton.
  „ donaciformis. *Lyc.* F. Leckhampton.
Trigonia *angulata. *Ag.* F. Leckhampton.
  „ clavicostata. *M.* and *L.* F. Leckhampton.
  „ costata. *Sow.* R. Leckhampton, Stroud, Cockbury, Burford, Stowell, &c.
  „ costatula. *M.* and *L.* F. Leckhampton.
  „ formosa. *O. G. S.* Cheltenham.
  „ lineolata. *Ag.* F. Leckhampton.
  „ tuberculosa. *Lyc.* F. Leckhampton.
  „ *V. costata. *Lyc.* F. Leckhampton.
  „ signata. *O. G. S.* Cheltenham.
  „ striata. *Sow.* P. Crickley.
  „ hemisphærica. *O. G. S.* Leckhampton.
Unicardium *parvulum. *M.* and *L.* P. Cleeve. R. Cockbury.
Venus curvirostris. *M.* and L. F. Leckhampton.
  „ trapeziformis. *Röm.* F. Leckhampton.

This dimyarian group, somewhat more extensive than that of the lias, is included mostly in the same genera, with some omissions, as Cardinia and Hippopodium.

FOSSILS OF THE INFERIOR OOLITE.

GASTEROPODA.

Bulla subquadrata. *Röm.* R. Stony-Cockbury.
Chemnitzia . . . sp.? P. Crickley.

Chemnitzia Oppellii. Cleeve.
Cirrus carinatus. *Sow.* R. Leckhampton.
„ *nodosus. *Sow.* P. Crickley. F. Leckhampton.
Cylindrites attenuatus. *M.* and *L.* F. Leckhampton.
„ mammillaris. *M.* and *L.* F. Leckhampton.
„ . . . sp. ? R. Andover's Ford.
Delphinula furcata. *Goldf.* F. Leckhampton.
Emarginula Leckhamptonensis. *M.* and *L.* F. Leckhampton.
„ scalaris. *Goldf.* F. Leckhampton.
Fissurella acuta. *Desl.* F. Leckhampton.
„ Brodiei. *M.* and *L.* F. Leckhampton.
Littorina ornata. *Sow.* P. Crickley.
Monodonta Lyellii. *D'Arch.* F. Leckhampton.
„ sulcosa. *D'Arch.* F. Leckhampton.
Natica *adducta. *Phil.* P. Crickley.
„ *Leckhamptonensis. *M.* and *L.* F. Leckhampton.
„ Pictavensis. Stroud.
„ . . . sp. ? R. Andover's Ford.
Naticella decussata. *Goldf.* F. Leckhampton.
Nerinæa . . . sp. ? F. Near Cheltenham. R. Andover's Ford.
Nerita cassidiformis. *M.* and *L.* F. Leckhampton.
„ costulata. *Sow.* P. Crickley.
„ lineata. *M.* and *L.* F. Leckhampton.
Patella *inornata. *Lye.* P. Crickley, Leckhampton.
„ nitida. *Desl.* F. Leckhampton.
„ retifera. *M.* and *L.* F. Leckhampton.
„ *rugosa. *Sow.* P. Crickley.
Phasianella turbiniformis. *M.* and *L.* F. Leckhampton.
Pileolus lævis. *Sow.* F. Leckhampton.
„ plicatus. *Sow.* F. Leckhampton.
Pleurotomaria *Aglaia. *D'Orb.* P. Crickley.
„ fasciata. *Sow.* R. Leckhampton, Sudeley.
„ *ornata. *Defr.* P. Crickley.
Rimula minutissima. *M.* and *L.* F. Leckhampton.
„ tricarinata. *Sow.* P. Crickley.
Trochotoma carinata. *M.* and *L.* P. Crickley.

It is somewhat singular to find among the nineteen genera of gasteropoda in the inferior oolite and thirteen genera in the lias, only four admitted as common to both—viz. Chemnitzia, Littorina, Natica, and Pleurotomaria. Patella, Emarginula, and Fissurella are remarkable additions in the oolitic period. All the genera are holostomatous.

FOSSILS OF THE INFERIOR OOLITE.

CEPHALOPODA.

Ammonites Brodiæi. R. Leckhampton.
„ concavus. *Sow.* R. Sudeley.

Ammonites Dorsetensis. *Wright.* R. Clapton near Northleach.
„ Martinsii. R. Stroud.
„ *Murchisonæ. *Sow.* P. Crickley, Leckhampton, &c.
„ Parkinsoni. *Sow.* R. Stroud.
„ Sowerbii. *Miller.* R. Leckhampton, Sudeley.
„ subradiatus. R. Stroud, Leckhampton, &c.
Nautilus inornatus. *D'Orb.*
„ lineatus. *Sow.* F. Leckhampton. R. Stanley.
„ *obesus. *Sow.* R. Leckhampton.
„ truncatus. *Sow.* P. Crickley. R. Leckhampton.
Belemnites Gingensis. *Oppel.* R. Leckhampton, Winchcombe, Cleeve.
„ giganteus. *Schl.* P. Crickley.
„ spinatus. *Quenstedt.* R. Stanley.

On considering this list of cephalopoda, we remark the poverty of the inferior oolite as compared with the immediately preceding sands, especially in ammonites. Very few of the liassic forms are continued into the oolite; and very few new forms have yet been collected from it in the Gloucestershire district. No ammonite is yet mentioned from the freestone (or middle) division; no belemnite; only one species of nautilus; though these genera are well represented in the pea-grit below and in the ragstone above. Probably more species of belemnites really occur, especially those allied to B. canaliculatus of Schlotheim.

PISCES.

Remains of this race of marine animals are uncommon in the inferior oolite of our district, nor are they plentiful anywhere in these strata in England. Teeth of Cestraciont sharks (Acrodus) are mentioned near Stroud.

REPTILIA.

These are rare fossils in the inferior oolite in all parts of England. At Cornwell, near Chipping-Norton, Plot observed the distal extremity of a large femur, and figured it on his eighth plate, fig. 4. (The reference on the plate to paragraph 155 of chap. v. is wrong; the description begins in paragraph 157.) This measured two feet round the condyles, and fifteen inches in the shank. It may have been the femur of a large megalosaurus or a small ceteosaurus. At Chapel-house, and another point near Chipping-Norton, and at Churchill, vertebræ and other bones of this huge saurian

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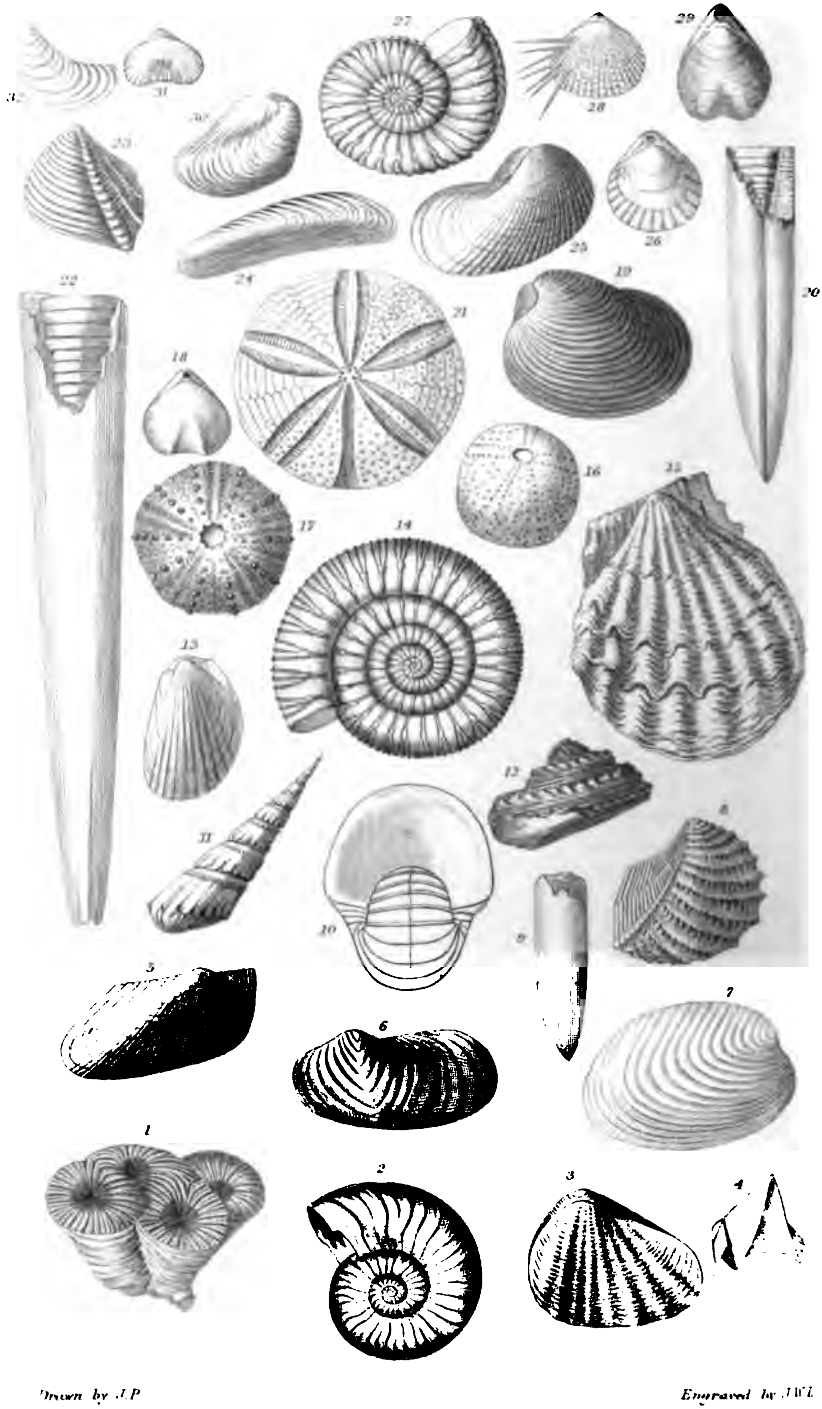
Pl. IX.

INFERIOR OOLITE



Drawn by J.P

Engraved by J.W.L.

have been found, and, according to the statements published, in the Inferior oolite. But the greater number of the remains of ceteosaurus have been discovered in higher strata, and it is likely in these instances they were found in Great oolite.

EXPLANATION OF PLATE IX., CONTAINING INFERIOR OOLITE FOSSILS.

1. Thecosmilia gregarea. *Edw.* Near Cheltenham.
2. Ammonites Murchisonæ. *Sow.* Near Cheltenham.
3. Pholadomya lirata. *Sow.* Near Seven Wells.
4. Rhynchonella cynocephala. *Rich.* Near Cheltenham.
5. Cucullæa elongata. *Sow.* Crosshands, Gloucestershire.
6. Goniomya angulifera. *Sow.* Seven Wells.
7. Astarte excavata. *Sow.* Leckhampton.
8. Trigonia striata. *Sow.* Crickley.
9. Belemnites Gingensis. *Quenst.* Leckhampton.
10. Nautilus lineatus. *Sow.* Stanley.
11. Nerinæa terebræformis. *Phil. MS.* Dorsetshire.
12. Pleurotomaria ornata. *Defr.* Dundry.
13. Lima gibbosa. *Sow.* Wegborough.
14. Ammonites Humphreysianus. *Sow.* Dundry.
15. Lima proboscidea. *Sow.* Leckhampton.
16. Collyrites ovalis. *Leske.* Dorsetshire.
17. Pedina Smithii. *Wright.* Dorsetshire.
18. Terebratula globata. *Sow.* Leckhampton.
19. Ceromya Bajociana. *D'Orb.* Rodborough.
20. Belemnites canaliculatus. *Schl.* Wotton-under-Edge.
21. Clypeus Plotii. *Klein.* Naunton.
22. Belemnites giganteus. *Schl.* Crickley.
23. Trigonia costata. *Sow.* Leckhampton Hill.
24. Modiola plicata. *Sow.* Crickley.
25. Pholadomya fidicula. *Sow.* Winchcombe Hill.
26. Terebratula fimbria. *Sow.* Seven Wells.
27. Ammonites Parkinsoni. *Sow.* Leckhampton Hill.
28. Rhynchonella spinosa. *Sow.* Winley Hill.
29. Terebratula perovalis. *Sow.* Winley Hill.
30. Modiola gibbosa. *Sow.* Cubberley.
31. Rhynchonella varians. *Dav.* Andover's Ford.
32. Ostrea acuminata. *Sow.* Cubberley.

The last four species are frequent in the fuller's-earth beds above the Inferior oolite near Bath and Cheltenham. A few interesting species are figured on this plate which have not yet been recognized in the district now specially under consideration.

FOSSILS OF THE FULLER'S-EARTH ROCK.

The division in the series of Bath oolites caused by the zone of marly limestones and clays, amongst which one portion was formerly found suitable for the fulling-mill, is nowhere now much exposed to observation, except in the vicinity of Bath. There its organic contents are not numerous, and are on the whole much assimilated to those of the inferior oolite. In the district of Gloucestershire, near Cheltenham and Northleach, where it is occasionally seen, the same aspect of the fauna is observed. Oxfordshire has only a feeble representative of the deposit. The list which follows includes several species from the Bath district, recorded by the Geological Survey, and others, marked (S.), described by Smith in 'Strata Identified,' 1816, and the 'Stratigraphical System,' 1817. No one had so much experience of fuller's-earth as Smith in his engineering operations[q]. His specimens are in the British Museum.

FOSSILS OF THE FULLER'S-EARTH ROCK.

ACTINOZOA.
- Anabacia orbulites. *Lam.* Cubberley.

ECHINODERMATA.
- Holectypus depressus. *Lam.* Bradford. (S.)

ANNELLIDA.
- Serpula crassa. *Sow.* Charlton-Horethorn. (S.)
- ,, quadrata. *Phil.* Orchardleigh. (S.)

BRACHIOPODA.
- Rhynchonella concinna. *Sow.* Cubberley.
- ,, spinosa. *Sow.* Somerset.
- ,, varians. *Dav.* Andover's Ford, Orchardleigh. (S.)
- Terebratula coarctata. *Sow* Corsham.
- ,, digona. *Sow.* Box.
- ,, globata. *Sow.* Bath.
- ,, maxillata. *Sow.* Cubberley.
- ,, ornithocephala. *Sow.* Box.
- ,, perovalis. *Sow.* Bath, Cubberley.

MONOMYARIA.
- Avicula echinata. *Sow.* Box, Cubberley.
- Gervillia. sp. Gloucestershire.
- Lima cardiiformis. *Sow.* Box.
- ,, duplicata. *Sow.* Somerset.
- ,, pectiniformis. *Zieten.* Monkton-Combe. (S.)

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[q] See Memoir of W. Smith, p. 60.

Ostrea acuminata. *Sow.* Cubberley.
,, Marshii. *Sow.* Monkton-Combe. (S.)
,, Sowerbii. *M.* and *L.* Cheltenham.
Pecten hemicostatus. *M.* and *L.* Cubberley.
,, vagans. *Sow.* Cubberley.

DIMYARIA.

Anatina undulata. *Sow.* Ancliff (S.), Wortley.
Astarte ovata. *Sow.* Gripwood. (S.)
Ceromya plicata. *Sow.* Gripwood. (S.)
,, Bajociana. *D'Orb.* Widcombe.
Cypricardia Bathonica. *D'Orb.* Box.
Goniomya angulifera. *Sow.* Box, Cubberley.
,, literata. *Sow.* Bradford.
Gresslya abducta. *Phil.* Gripwood. (S.)
Homomya gibbosa. *Sow.* Mitford (S.), Cubberley.
Isocardia. sp. Gloucestershire.
Lithodomus. sp. Near Bath. (S.)
Modiola reniformis. *Sow.* Gloucestershire.
,, Sowerbyana. *Bronn.* Ancliff (S.), near Cheltenham.
Myacites Terquemii. *Buv.* Cubberley.
,, (Unio. sp.? *Smith.*) Gripwood. (S.)
Pholadomya lyrata. *Sow.* Cubberley.
,, Murchisonæ. *Sow.* Cubberley.
Tancredia triangularis. *Lye.* Gripwood. (S.)
Trigonia costata. *Sow.* Bath.
,, clavellata. *Sow.* Orchardleigh.

GASTEROPODA.

Nerinæa. sp. Cubberley.
Pleurotomaria. sp. Charlton-Horethorn. (S.)

CEPHALOPODA.

Ammonites modiolaris. *Smith.* Rowley-Bottom. (S.)
,, sp. *Smith.* Broadfield Farm. (S.)
Belemnites parallelus. *Phil.* Charlton-Horethorn. (S.)
Nautilus. sp. *Smith.* Lansdown. (S.)

STONESFIELD BEDS.

The lowest zone of the Great oolite, represented in Oxfordshire and Gloucestershire by shelly laminated roofing flags and sands, was carefully noted and measured by Smith in the hills above Bath[r]. Lonsdale extended an equally accurate examination to Eyeford in Gloucestershire and Stonesfield in Oxfordshire, beyond which the very similar, but probably older, Collyweston beds near Stamford were, till within a few years, believed to continue the zone, which has another analogue in the Brandsby beds of Yorkshire. The fossils of the 'Stonesfield slate' furnish on the whole so large and instructive a series of life-forms, and were accumulated under so much of local peculiarity, as to require a separate enumeration. Mr. Buckman in his Geology of Cheltenham gives a considerable number of the Eyeford fossils. In 1855, I made a catalogue of the vegetable and animal remains at Stonesfield[s]; in 1860, Mr. J. Whiteaves, a most successful explorer of the Oxford district[t], added twenty-eight species of mollusca. Many of the fossils of these remarkable beds are identical with those of higher zones in the Great oolite, and may be known by the figures of Morris and Lycett in the Palæontographical Society's Memoirs.

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[r] Memoir of W. Smith, p. 60.

The following Catalogue represents the state of my knowledge of the flora and fauna of Stonesfield, meaning by this the flaggy and sandy series exclusively. Some determinations by Professor Buckman and the Ordnance Geological Survey have been added for localities other than Stonesfield.

FOSSILS OF THE STONESFIELD BEDS.

PLANTS.

Algæ.

Halymenites ramulosus. *Br.* Stonesfield.

Filices.

Cyclopteris latifolia. *Phil.* Eyeford.
Glossopteris longifolius[u]. *Buck.* Eyeford.
Hymenopteris macrophylla. *Br.* Stonesfield.
Pecopteris approximata. n. s. *Phil.* Stonesfield.
„ diversa. n. s. *Phil.* Stonesfield.
„ incisa. n. s. *Phil.* Stonesfield.
Sphænopteris cysteoides. *L.* and *H.* Stonesfield.
„ plumosa. n. s. *Phil.* Stonesfield.
Tæniopteris latifolia. *Br.* Stonesfield.
„ angustata. n. s. *Phil.* Stonesfield.
„ scitamineæ-folia. *Stern.* Stonesfield.

Monocotyledoneæ.

Aroides Stutterdi. *Carr.* Stonesfield.

The following petiolate, lanceolate leaves are referred by Mr. Buckman to the Monocotyledonous division of plants. They may perhaps be Cycads allied to the Mexican genus Dion :—

Bensonia ovata. *Buck.* Sevenhampton.
Lilia lanceolata. *Buck.* Eyeford.

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[s] Oxford Essays.

[t] Reports of the British Association, 1860, p. 104.

[u] Figured by Buckman, Geol. of Cheltenham, Plate I. fig. 1, as Salicites.

Naiadea obtusa. *Buck.* Sevenhampton.
„ ovata. *Buck.* Eyeford, Sevenhampton.
Stricklandia acuminata. *Buck.* Sevenhampton.
Cycadaceæ.
Bucklandia squamosa. *Stern.* Stonesfield.

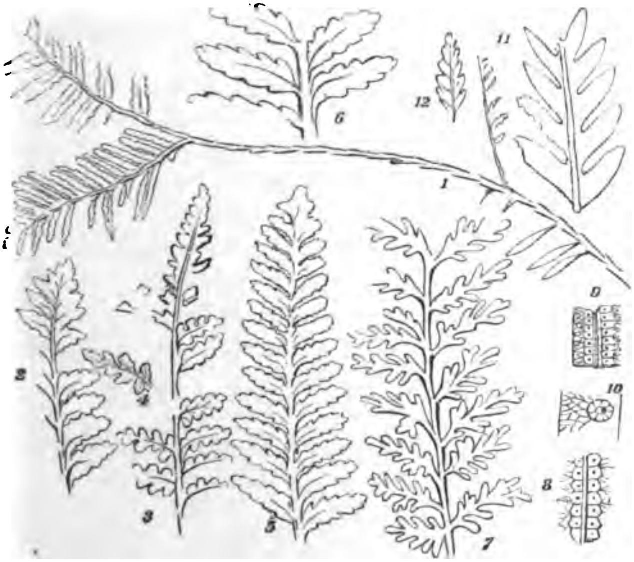

Diagram XXVIII. Stonesfield ferns (Filices).

1. Pecopteris diversa. n. s. *Phil.* Branching fern, remarkable for different forms of leaf: on the lower part lanceolate and petiolate, in the upper part sessile, and apparently springing in pairs of narrow leafits. This is believed to arise from the removal of the midrib. 2. Pecopteris approximata, n. s., shewing the termination; the leafits sessile, closely placed, and slightly crenated. 3. Sphænopteris plumosa, n. s. *Phil.*; the leafits lobed, separate. 4. Shewing somewhat of the nervures. 5. Pecopteris incisa, n. s. *Phil.*; more sharply crenated than fig. 2, and the leafits more separate. 6. Enlargement to shew the form of the leafit. 7. Sphenopteris cysteoides. *Lindley.* The specimens drawn for Foss. Flor. t. 176. It is perhaps not a fern, but one of the curious coniferous plants noticed in reference to Diagram XXXI. 8, 9, 10. Tæniopteris angustata, n. s., *Phil.*, shewing the sporangia and the nervures. 10. Enlargement. 11 and 12. Undetermined plant, apparently cycadeous. No distinct nervures. 12. The termination of a leaf.

Palæozamia longifolia. *Phil.* Stonesfield.
„ megaphylla. n. s. *Phil.* Stonesfield.
„ pecten. *Phil.* Stonesfield.
„ pectinata. *L.* and *H.* Stonesfield.
„ taxina. *L.* and *H.* Stonesfield.

Pterophyllum Buckmanni[1]. n. s. *Phil.* Sevenhampton.
" comptum. *Phil.* Stonesfield.
" minus? *Brong.* Stonesfield.

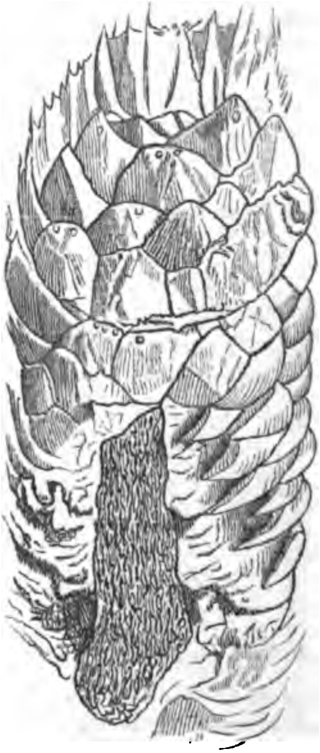

Diagram XXIX. Bucklandia squamosa. *Brongn.*

Unique specimen, on a slab of Stonesfield slate. The drawing, made of half size, represents an interior axis with longitudinal furrows enclosing lanceolate spaces. These appear to have furnished vascular bundles. Almost in contact with this axis are the leaves or scales, seen externally in the upper part, and edgeways on the right hand, where they suggest the idea of a twisted base and a longitudinal implantation. They cannot, however, be traced to actual attachment. The apices of a few of the scales or leaves have a rhomboidal cicatrix, or short furrows, and one or two small oval prominences appear on the same or other scales. On the same specimen is a leaf or fruit scale, 3·3 inches long, with an amygdaloidal end two inches long, having rows of minute punctures. The leaves or scales on the stem are finely striated in a longitudinal direction, without any sign of midrib.

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[1] The figure is given by Buckman, Geol. of Cheltenham, Plate I. fig. 3, under the title of Cycadites.

Coniferæ.

Taxites podocarpioides. *Br.* Stonesfield.
Thuytes articulatus. *Stern.* Stonesfield.
„ cupressiformis. *Stern.* Stonesfield.
„ divaricatus. *Stern.* Stonesfield.
„ expansus. *Stern.* Stonesfield.

FRUITS.

Carpolithus diospyriformis. *Stern.* Stonesfield.

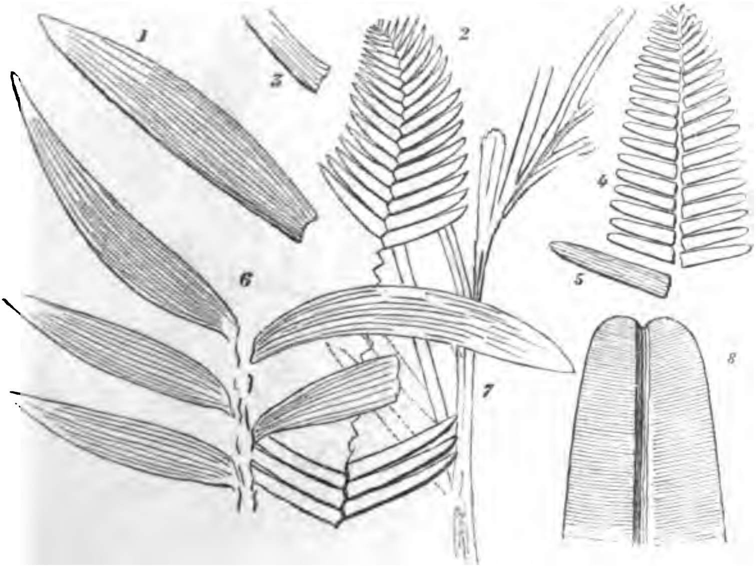

Diagram XXX. Stonesfield Cycadaceæ.

1. Leaf of Palæozamia megaphylla, often twelve inches long. 2. Palæozamia pectinata. *Sternberg*, t. 111, f. 1. Inner or upper face. 3. To shew the nervure. 4. Palæozamia taxina. *L.* and *H.*, t. 175. Outer or lower face. 5. To shew the nervure. 6. Palæozamia longifolia. *Phil.* 7. Ramose plant. Tax. podoc.? 8. Tæniopteris scitamineæ-folia. *Sternberg*, t. 37, f. 2.

Carpolithus Lindleyanus. *Gutl.* Stonesfield.

These plentiful fruits (Diag. XXXII.) are probably cycadaceous, belonging to Palæozamia.

Fruit of a Thuytes.

Fruit scales of Araucarites Brodiæi. *Carr.* Stonesfield.

FORAMINIFERA occur in the centres of the oolitic grains.

ACTINOZOA.

Anabacia orbulites. *Lam.* Stonesfield.
Montlivaltia Smithii. *Dunc.* Stonesfield.

Cyathophoræ, Isastrææ, and Thamnastrææ are commonly obtained from the Great oolite at Stonesfield, but rarely from the slaty beds. Mr. Buckman gives several other genera from the clay which overlies the slaty beds at Sevenhampton; but he regards this clay as belonging to a later stage (Bradford clay).

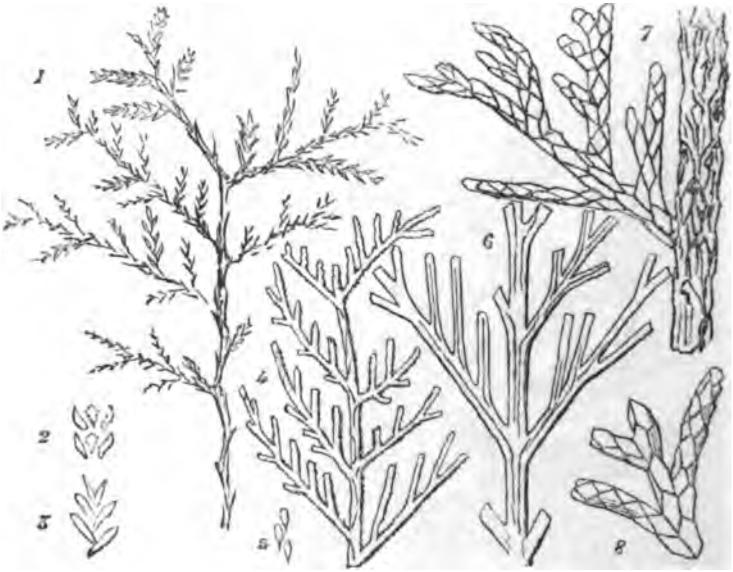

Diagram XXXI. Stonesfield Coniferæ.

1. Thuytes articulatus. *Sternberg*, t. 33, f. 3. 2. Arrangement of some of the leafits. 3. Arrangement of others. 4. Thuytes expansus? *Sternberg*, t. 38. f. 2. 5. Surface of the small branches. 6. Taxites podocarpioides? Brong. V. F. 7. Thuytes divaricatus. *Sternberg*, t. 39. 8. Ditto.

FOSSILS OF THE STONESFIELD BEDS.

ECHINODERMATA.

Asteroidea.

Astropecten Cotteswoldii. *Buck.* Eyeford.
„ Wittsii. *Wright.* Eyeford.

Echinoidea.

Acrosalenia hemicidaroides. *Wright.* Stonesfield.

Cidaris propinquus. *Goldf.* Eyeford. J. B.
Clypeus Plotii. *Klein.* Stonesfield.
Echinobrissus clunicularis. *Lhwyd.* Stonesfield.
Hemicidaris Stokesii. *Wright.* Stonesfield.
Pseudodiadema Parkinsoni. *Wright.* Stonesfield.

Mr. Buckman cites from the clay at Sevenhampton Cidaris subangularis, *Goldf.*, Holectypus depressus, *Lam.*, and joints of Apiocrinus.

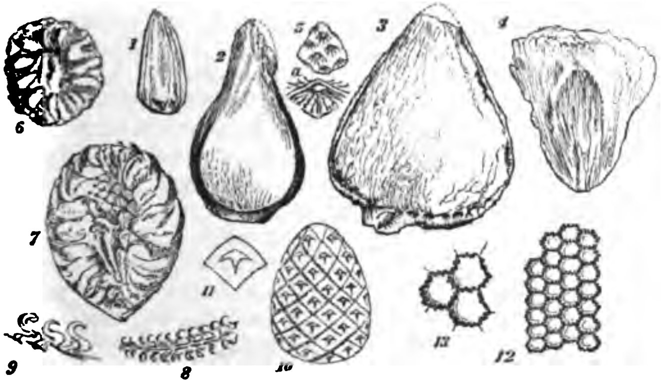

Diagram XXXII. Stonesfield Fruits, &c.

1. Carpolithus Lindleyanus. F. F. t. 193. A. 2. Carpolithus diospyriformis. *Sternberg*, t. 37, f. 6. 3. The same. Great oolite of Enslow Bridge. 4. Araucarites Brodiæi. *Carruthers.* 5. Fruit of Thuytes—one of the Cupressineæ. *a.* Enlarged view of one of the impressions. 6, 7, 8, 9. Fruit of the same. 10 and 11. Fruit of Thuytes expansus. After Buckman, Geology of Cheltenham, t. 1, f. 6. 12. Aroides Stutterdi. *Carruthers.* Geol. Mag., April 1867. 13. Enlargement of the same.

FOSSILS OF THE STONESFIELD BEDS.

Annellida.

Serpula ilium. *Goldf.* Eyeford, Sevenhampton, Stonesfield.

Cirripedia.

Pollicipes ooliticus. *Buck.* Eyeford, Sevenhampton.

Crustacea.

Glyphea rostrata. *Phil.* Stonesfield.
Prosopon mammillatum. *Woodw.* Stonesfield.

Insecta.

Blapsidium Egertoni. Stonesfield.

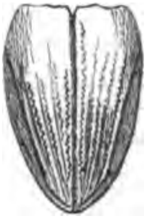

Diagram XXXIII.
Buprestidium. Stonesfield.

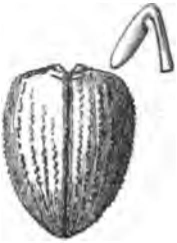

Diagram XXXIV.
Curculionidium. Stonesfield.
The saltatorial leg is separate.

Buprestidium. Stonesfield, Eyeford.
Curculionidium. Eyeford, Stonesfield.

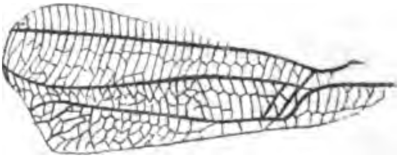

Diagram XXXV. Hemerobioides giganteus. *Westwood.*

Hemerobioides giganteus. *Buckl.* Stonesfield.
Libellula Westwoodii. *Phil.* Stonesfield.

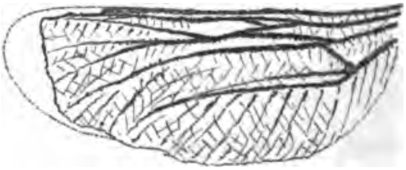

Diagram XXXVI. Libellula Westwoodii. *Phil.*

Melolonthidium. Eyeford, Stonesfield.
Prionideum. Stonesfield.

POLYZOA have not yet occurred to my observation in these strata.

BRACHIOPODA.

Rhynchonella concinna. *Sow.* Stonesfield.
„ farcta. *Linn.* Stonesfield.
„ obsoleta. *Sow.* Stonesfield.
Terebratula maxillata. *Sow.* Stonesfield.

MONOMYARIA.

Avicula Munsteri. *Goldf.* Eyeford, Sevenhampton.
Gervillia acuta. *Sow.* Stonesfield.
„ ovata. *Sow.* Eyeford, Sevenhampton.
„ subcylindrica. *M.* and *L.* Stonesfield.
Hinnites abjectus. *Phil.* Stonesfield.
Inoceramus amygdaloides. *Goldf.* Stonesfield.
„ Fittoni. *M.* and *L.* Stonesfield.
„ obliquus. *M.* and *L.* Stonesfield.
Lima cardiiformis. *M.* and *L.* Stonesfield, Eyeford.
„ duplicata. *Sow.* Stonesfield, Sevenhampton.
„ elongata. *Gold.* Sevenhampton.
„ impressa. *M.* and *L.* Stonesfield.
„ minuta. *Gold.* Sevenhampton.
„ pectiniformis. *Schl.* Stonesfield.
Ostrea acuminata. *Sow.* Stonesfield.
„ gregarea. *Sow.* Stonesfield.
„ Sowerbii. *M.* and *L.* Stonesfield.
Pecten annulatus. *Sow.* Eyeford, Stonesfield.
„ lens. *Sow.* Eyeford, Stonesfield.
„ personatus. *Goldf.* Stonesfield.
„ retiferus. *M.* and *L.* Stonesfield.
„ vagans. *Sow.* Stonesfield.
Perna rugosa. *Goldf.* Stonesfield.
Pinna ampla. *Sow.* Stonesfield, Sevenhampton.
„ cuneata. *Bean.* Stonesfield.
Placunopsis radians. *M.* and *L.* Stonesfield.
„ socialis. *M.* and *L.* Stonesfield.
Pteroperna pygmæa. *M.* and *L.* Stonesfield.

DIMYARIA.

Arca lævis. *Buck.* Wagborough Bush.
Astarte angulata. *M.* and *L.* Stonesfield.
„ elegans. *Sow.* Stonesfield.
„ pumila. *Sow.* Stonesfield.
„ squamula. *D'Arch.* Stonesfield.
„ Wiltoni. *M.* and *L.* Stonesfield.
Cardium acutangulum. *Phil.* Stonesfield.
„ striatum. *Buck.* Sevenhampton.
„ Stricklandi. *M.* and *L.* Stonesfield.
Ceromya Symondsii. *M.* and *L.* Stonesfield.
Corbula involuta. *Goldf.* Stonesfield.
Cucullæa triangularis. *Phil.* Stonesfield.
Gresslya abducta. *Phil.* Stonesfield.

Lucina crassa. *Sow.* Great Tew.
Macrodon Hirsonensis. *D'Arch.* Stonesfield.
Modiola compressa. *Portl.* Stonesfield.
„ gibbosa. *Sow.* Sevenhampton, Eyeford.
„ imbricata. *Sow.* Stonesfield.
„ Sowerbyana. *D'Orb.* Stonesfield.
Myacites æquatus. *Phil.* Near Naunton.
„ calceiformis. *Phil.* Stonesfield.
Mytilus pulcher. *Goldf.* Eyeford.
„ sublævis. *Sow.* Stonesfield.
Neæra Ibbetsoni. *M.* and *L.* Stonesfield.
Nucula axiniformis. *Phil.* Eyeford.
„ mucronata. *Sow.* Wagborough Bush.
Opis lunulatus. *Sow.* Stonesfield.
Pholadomya acuticosta. *Sow.* Great Tew, Stonesfield.
„ lyrata. *Sow.* Sevenhampton.
Pholas oolitica. *M.* and *L.* Stonesfield.
Quenstedtia oblita. *Phil.* Stonesfield.
Tancredia brevis. *M.* and *L.* Stonesfield.
„ curtansata. *Phil.* Stonesfield.
„ planata. *M.* and *L.* Stonesfield.
Trigonia costata. *Sow.* Stonesfield.
„ impressa. *Sow.* Stonesfield.
„ Moretoni. *M.* and *L.* Stonesfield, Little Tew.
Unicardium. Stonesfield.

GASTEROPODA.

Actæon cuspidatus. *Sow.* Wagborough Bush.
Alaria trifida. *Phil.* Stonesfield.
Cerithium. Wagborough.
Chemnitzia Hamptonensis. *M.* and *L.* Stonesfield.
Deslongchampsia Eugenii. *M.* and *L.* Stonesfield.
Eulima communis. *M.* and *L.* Stonesfield.
Fusus Buvignieri ? *M.* and *L.* Stonesfield.
Littorina concinna. *Röm.* Wagborough Bush.
Natica canaliculata. *M.* and *L.* Stonesfield.
„ intermedia. *M.* and *L.* Stonesfield.
Nerinæa Voltzii. *Desh.* Stonesfield.
Nerita costulata. *Desh.* Stonesfield.
„ hemisphærica. *Röm.* Stonesfield.
„ minuta. *Sow.* Eyeford, Wagborough, Stonesfield.
„ rugosa. *M.* and *L.* Stonesfield.
„ spirata. *Sow.* Eyeford, Wagborough.
Neritopsis striata. *M.* and *L.* Stonesfield.
Patella Römeri. Stonesfield.
„ lata. *Sow.* Stonesfield, Wagborough.
„ nana. *Sow.* Wagborough.
„ rugosa. *Sow.* Stonesfield, Wagborough.
Trochus obsoletus. *Röm.* Sevenhampton.
„ spiratus. *D'Arch.* Stonesfield.

Actæonina parvula. Stonesfield.
Amberlya nodosa. Stonesfield.
Nerinæa funiculus. Stonesfield.
„ gracilis. Stonesfield.
Turbo ornatus. *Sow.* Eyeford, Sevenhampton.

CEPHALOPODA.

Ammonites bullatus. *D'Orb.* Stonesfield.
„ gracilis. *Buck.* Stonesfield, Sevenhampton.
„ hecticus. *O. G. S.* Stonesfield.
„ micromphalus. n. s. *Phil.* Stonesfield.
„ triplex. *Sow.* Sevenhampton.
„ Waterhousii. *M.* and *L.* Stonesfield.
Belemnites ari-pistillum. *Lhwyd.* Stonesfield, Eyeford.
„ Bessinus. *D'Orb.* Stonesfield, Eyeford.
Nautilus Baberi. *M.* and *L.* Stonesfield.

FISHES. These are all from Stonesfield; some of them occur at Eyeford and Sevenhampton. The names are chiefly from Agassiz.

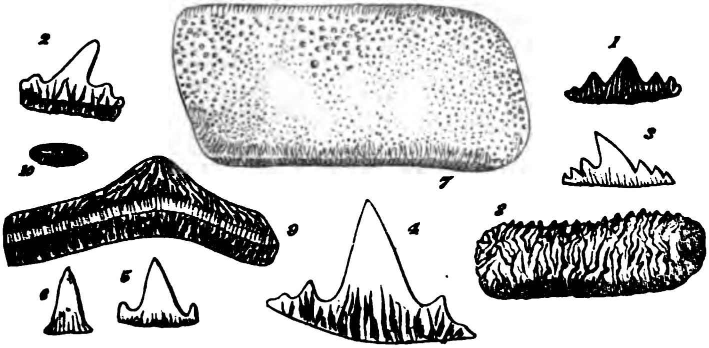

Diagram XXXVII. Teeth of Placoid Fishes. Stonesfield. Natural size.

1. Hybodus jugosus. *Phil.* 2. Hybodus polyprion. *Ag.* 3. Hybodus polyprion. *Ag.* Perfect. 4. Hybodus grossiconus. *Ag.* 5. Hybodus grossiconus. Largest example. 6. Hybodus grossiconus, without lateral denticles. 7. Strophodus magnus. *Ag.* Surface worn smooth in places. 8. Strophodus lingualis, *Phil.*, with unworn surface. 9. Strophodus tenuis. *Ag.* Perfect surface, like Acrodus. 10. Acrodus.

Cestraciontidæ.

Acrodus leiodus.
Asteracanthus tenuisulcatus.
Ceratodus Phillipsii.
Leptacanthus serratus.
„ tenuistriatus.
Nemacanthus brevispinus.
Pristacanthus securis.
Strophodus favosus.
„ magnus.
„ tenuis.
„ lingualis. n. s. *Phil.*

Hybodontidæ. Hybodus apicalis. " dorsalis. " grossiconus. " marginatus. " polyprion.	Dorsal spines and teeth detached, occasionally waterworn.
Edaphodontidæ. Ganodus Bucklandi. " Colei. " curvidens.	Jaws which are minutely denticulated, or else fulfil the functions of teeth.

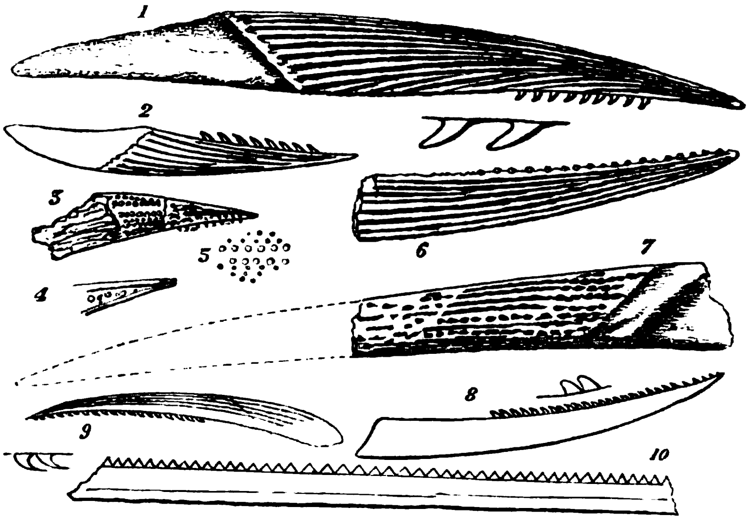

Diagram XXXVIII. Stonesfield Fishes—Spines.

1. Hybodus dorsalis. *Ag.* Oxford Museum. (The denticles below.) 2. Hybodus apicalis. *Ag.* 3. Nemacanthus brevis. *Phil.* Oxford Museum. 4. Termination of the spine. 5. The granulated surface. 6. Hybodus marginatus. *Ag.* 7. Asteracanthus tenuistriatus. *Ag.* 8. Leptacanthus serratus. *Ag.* (The denticles above.) 9. Leptacanthus semistriatus. *Ag.* Oxford Museum. (The denticles below.) 10. Pristacanthus securis. *Ag.*

Ganodus dentatus. " emarginatus. " falcatus. " neglectus. " Oweni. " psittacinus. " rugulosus. *Pycnodontidæ.* Gyrodus perlatus. " trigonus.	These are usually mesodorsal spines, sometimes worn by attrition, and rarely quite perfect.

Gyronchus oblongus.
Pycnodus Bucklandi.
,, didymus.
,, Hugii.
,, latirostris.
,, obtusus.
,, ovalis.
,, parvus.
,, rugulosus.
,, trigonus.
Scaphodus heteromorphus.

These teeth are often found in their proper relative place, lying in the stone with no trace of the bone to which they were attached.

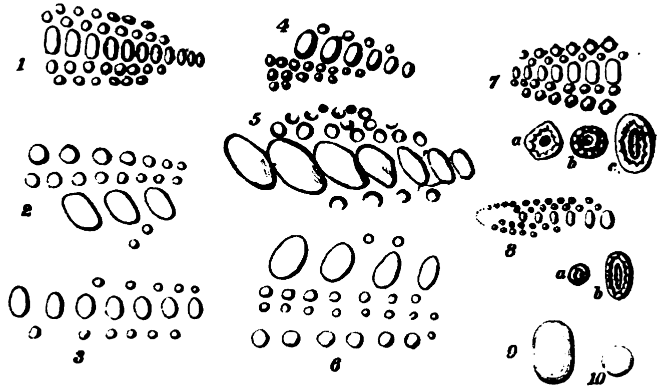

Diagram XXXIX. Pycnodont Fishes of Stonesfield.

1. Pycnodus rugulosus. *Ag.* 2. Pycnodus Hugii. *Ag.* 3. Pycnodus ovalis. *Ag.* 4. Pycnodus Bucklandi. *Ag.* (A lateral row of teeth.) 5. Pycnodus Bucklandi. *Ag.* (A lateral row of teeth.) 6. Pycnodus didymus. *Ag.* 7. Gyrodus trigonus. *Ag.* *a.* One of the outside teeth. *b.* One of the intermediate teeth. *c.* One of the middle row of teeth. 8. Gyronchus oblongus. *Ag.* *a.* One of the smaller teeth. *b.* One of the middle row. 9. Pycnodus Bucklandi, from the middle of a central row of teeth. 10. Pycnodus, from an outside row—perhaps of P. rugulosus.

Lepidoidei.
Lepidotus unguiculatus.
,, tuberculatus.
Pholidophorus minor.
Sauroidei.
Belonostomus leptosteus.
Caturus pleiodus.
Macrosemius brevirostris.
Sauropsis mordax.

Jaws and teeth usually solitary; scales almost constantly single, none materially injured by attrition.

Coelacanthi.
Ctenolepis cyclus.

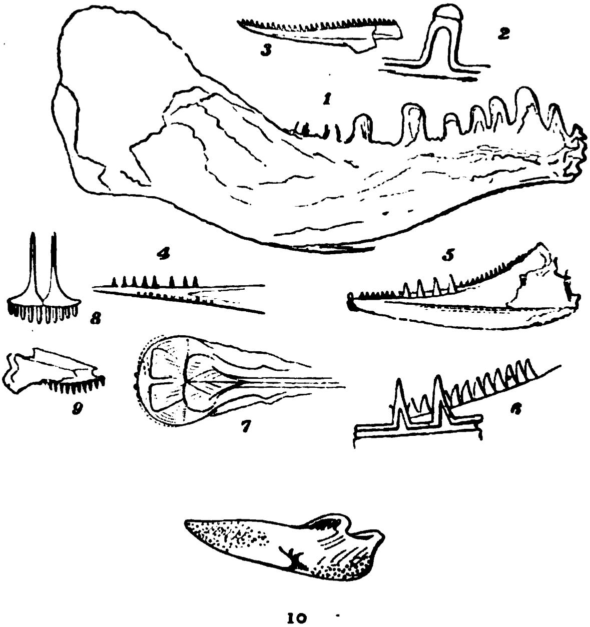

Diagram XL. Fishes of Stonesfield.

1. Lower jaw of Pycnodus rudis. *Phil.* 2. Enlarged tooth, shewing the hemispherical top, and internal cavity communicating with a nutrient canal. 3. Belonostomus flexuous. *Phil.* Lower jaw. 4. Belonostomus leptosteus. *Ag.* Lower jaw. 5. Pholidophorus minor? *Ag.* 6. Magnified view to shew the inner range of small close equal teeth, and the outer range of larger and more distant teeth. 7. Cranial bones of Pholidophorus minor of Agassiz. 8. Intermaxillary bone and teeth of Pholidophorus minor? 9. Maxillary bone and teeth of Pholidophorus minor of Agassiz? 10. Uncertain.

REPTILIA.
Chelonida.
Testudo Stricklandi. *Phil.*
Ichthyopterygida.
Ichthyosaurus advena. *Phil.*
Sauropterygida.
Plesiosaurus erraticus. *Phil.*
Crocodilida.
Teleosaurus brevidens. *Phil.*
„ subulidens. *Phil.*
Deinosaurida.
Megalosaurus Bucklandi. *Meyer.*
Pterosaurida.
Rhamphorhynchus Bucklandi. *Meyer.*

All these are scattered in the midst of marine shells, crustacea, echinida, corals, and land plants, occasionally worn, often broken. Teleosaurus is more frequent in the oolite above the Stonesfield beds.

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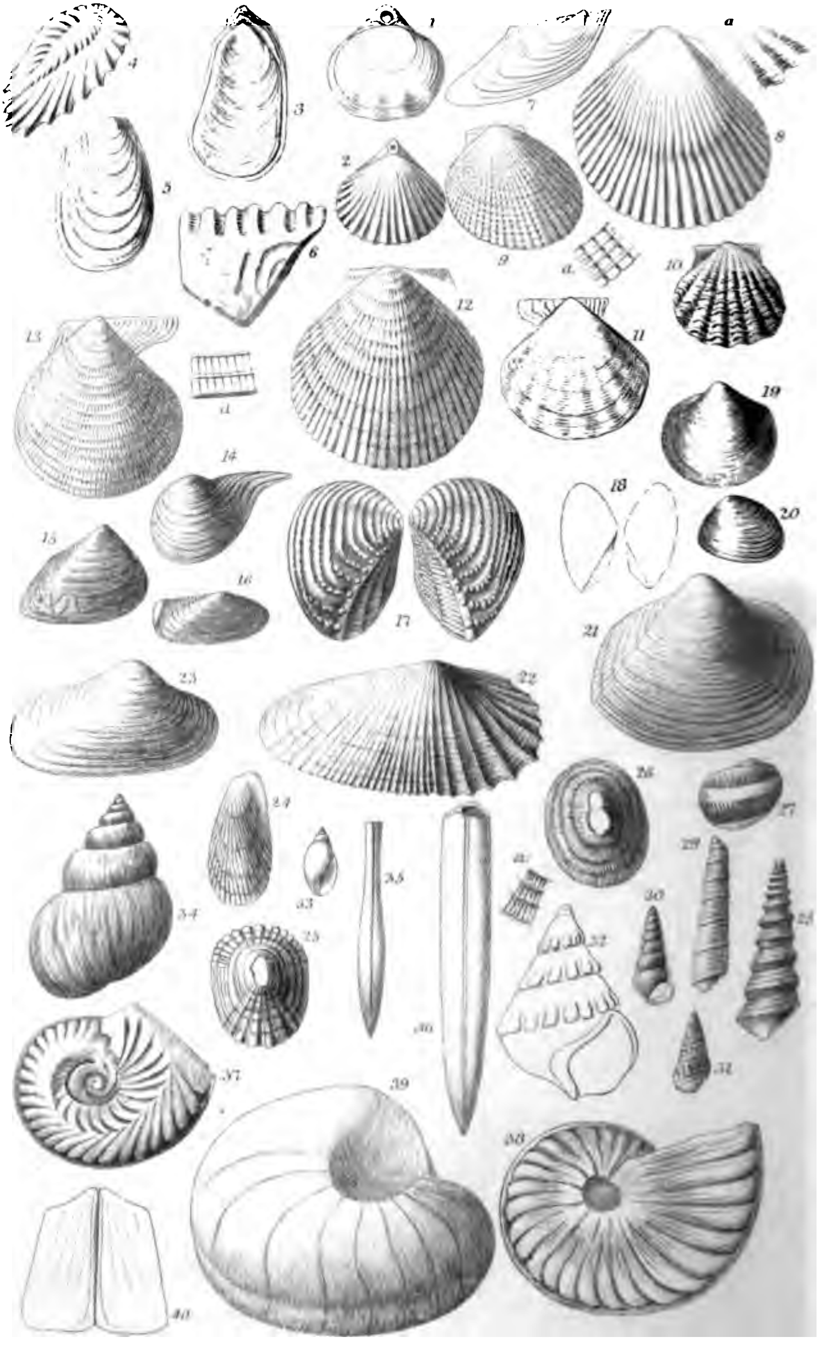
STONES'FIELD BEDS.



Drawn by J. P.

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EXPLANATION OF PLATE X, CONTAINING STONESFIELD FOSSILS.

1. Terebratula maxillata.
2. Rhynchonella obsoleta.
3. Ostrea Sowerbii.
4. „ gregarea?
5. Inoceramus obliquus.
6. Perna rugosa. Fragment.
7. Gervillia acuta.
8. Lima cardioides. *a.* Radiations.
9. „ punctata. *a.* Radiations.
10. Pecten vagans.
11. „ fibrosus.
12. „ retiferus.
13. „ annulatus.
14. Neæra Ibbetsoni.
15. Trigonia Moretoni, shewing the beginning of the folds.
16. Quenstedtia oblita.
17. Trigonia impressa.
18. Tancredia arguta.
19. Unicardium gibbosum.
20. Astarte angulata.
21. Cardium subtrigonum.
22. Pholadomya acuticosta.
23. Myacites æquatus.
24. Mytilus furcatus.
25. Patella Römeri.
26. „ lata. *a.* The radiation.
27. Nerita costulata, var. bicincta. Two white bands on a purple ground.
28. Nerinæa funiculus?
29. „ gracilis.
30. Eulima communis.
31. Ceritella conica.
32. Amberlya nodosa. Outline from Morris and Lycett, Ool. Foss.
33. Actæonina parvula.
34. Phasianella elegans.
35. Belemnites ari-pistillum.
36. „ Bessinus.
37. Ammonites Waterhousei.
38. „ micromphalus. *n. s.*
39. Nautilus Baberi.
40. Bivalvular operculum, probably of Nautilus Baberi.

TESTUDO STRICKLANDI. *Phil.*

The scales represented in the Diagram, No. XLI. figs. 10, 11, are selected as median scales of the one species of tortoise found in the Stonesfield beds. Only scales, and these separate, have yet been noticed, if we except a very short phalangal bone which may have belonged to the fore foot. Professor Owen notices these remains in his Report on Fossil Reptiles to the British Association, 1841. In his opinion they probably belong to a terrestrial species of ordinary size—say ten inches in length. Mr. H. E. Strickland took some pains to collect these scutes, of which the Oxford Museum possesses a good series.

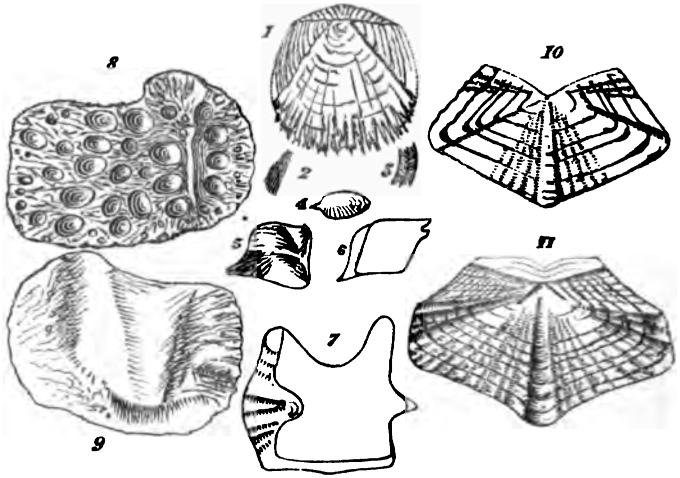

Diagram XLI. Scales and Scutes (Stonesfield).

1. Ctenolepis cyclus. *Ag.* The external aspect with striated surface shewn in the middle, at the sides the interior concentric lines of bone, above the radiated impression of the lower and forward surface of the scale. 2. The radiated striation on the external face. 3. The concentric striation. 4. Small scale supposed to be of the same species. 5. Lepidotus unguiculatus. *Ag.* 6. Another scale. 7. Another large unguiculate scale. 8. Scute from the side of Teleosaurus brevidens; external aspect. 9. Interior of the same. 10. Scute from the middle dorsal row of Testudo Stricklandi—outside. 11. Another also from the middle row, seen on the inner side.

ICHTHYOSAURUS ADVENA. *Phil.*

Very few remains of this marine or even pelagic genus occur among the reliquiæ of the littoral lagoon of Stonesfield. Only vertebræ have been recorded.

PLESIOSAURUS ERRATICUS. *Phil.*

A few cervical vertebræ belonging to a small species of this genus have occurred at Stonesfield, and perhaps a few teeth and a portion of lower jaw belong to the same. They hardly afford specific characters for distinction from others which occur in the oolites, but it is convenient to give a name for reference.

TELEOSAURUS.

Teleosaurus, a genus of mesozoic crocodiles, first made known in England by the discovery of entire specimens at Whitby, is not recorded in the country round Oxford in any rock older than the Stonesfield beds. It is rarely mentioned at all further south in England, but occurs in the oolite of Normandy. Formed for aquatic motion, and associated with marine remains, its ordinary way of life may be understood by analogy with the sharp-nosed crocodile of St. Domingo, which ventures pretty freely out to sea,—more so than the crocodile of the Senegal and the Nile, the caïman of America, or the gavial of the Ganges.

Adopting the gavial for a general term of comparison, we remark, first, the correspondence of size between the modern Eastern and the old Western saurian. The gavial reaches a length of fifteen or eighteen feet, and this is about the size of the largest fossil yet measured. The large teleosaurus of Whitby measures fifteen feet two inches, a portion of the beak wanting. Judging by the breadth of the cranium (thirteen inches), the whole head has been estimated at four feet and a half, and the entire length from the beak to the end of the tail, eighteen feet. The head length assumed is perhaps too great; but as there are only thirty-three out of forty-two vertebræ in the tail, the entire length may have been as supposed. In the gavial the head constitutes between one-fifth and one-sixth of the whole length, the tail less than one-half. The measure of the longest head-bones of teleosaurus from the Oxford district is 31·0 inches, indicating a total length not exceeding fifteen feet; but portions of the jaws and fragments of limb bones indicate a somewhat greater size to be occasionally attained.

The following Table contains some useful proportionate measures, referred to a uniform length of 180 inches measured on the skeleton, without allowance for intervertebral cartilage, which would increase the total length about ten inches. The head-length is between the occipital condyle and the end of the intermaxillary bones :—

Lengths.	Gavial of the Ganges.	Teleosaurus of Stonesfield.	Teleosaurus of Whitby.	Crocodile of the Nile.	Crocodile of India.
Total	180	180	18	180	180
Head, mesial line .	32	32	45	28 or 26·0	27
Cervical v. . . .	64	64	64	68	63
Dorsal v. . . .					
Lumbar v. . . .					
Sacral					
Caudal	84	84	84	85	90
Lower jaw, measured on the mesial line	36	36·2	..	30	32
Symphysis	19·7	16·7	..	5	5
Post articular . . .	5	5·1	..	3·8	4

For a considerable period the long slender jaws of these truly aquatic crocodiles have been observed at Stonesfield and some other places in the Great oolite near Oxford, as Enslow Bridge and Kidlington. The Oxford Museum contains specimens sufficient for determining the principal characters of the teeth, head, vertebral column, and hind limb. Two species must be admitted, distinctive characters being found in the teeth, lower jaw, and cervical vertebræ. If we were guided by the differences among the teeth, which seem to be teleosaurian, more than two species would be allowed at Stonesfield and Enslow Bridge.

In Diagram No. XLII. the various patterns of ornamental striation on the teeth appear. In fig. 1. two rather short teeth appear in their separate sockets, a little curved, uniformly striated, the striæ growing more prominent toward the point and finer toward the base. There is but slight trace of *bicarination* on these teeth, near the apex, which is usually blunt, even if not much worn. Teeth of this pattern appear in different parts of the jaws, and they agree with that of a teleosaurus from the oolite of Soleure (Plate. VI. fig. 7. *Ossem. Fossiles*). They are less numerous than in Teleosaurus Cadomensis, which, in the opinion of Cuvier, had 180 teeth. The Stonesfield and Enslow fossils had about 140.

In fig. 2 we have a longer bicarinate tooth, the carinæ prominent near the apex, and then subsiding into a conspicuous divisional stria, to which on either side other striæ gather obliquely, as in fig. 3. I regard this tooth as belonging to the same species as fig. 1, which I have named Teleosaurus brevidens.

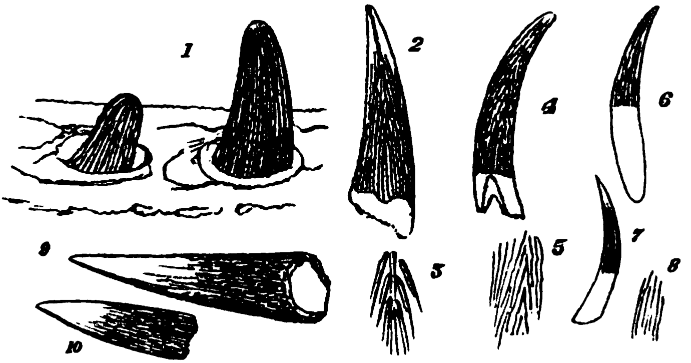

Diagram XLII. Teeth of Teleosaurians.

1. Teleosaurus brevidens, shewing a full-grown and also a young tooth in the sockets; striæ stronger toward the point, finer toward the base. 2. A specimen, shewing the sharp keel near the apex; figure curved. 3. Magnified view of the striation on the side of the carina. 4. A long, narrow, much curved tooth. 5. The striation textilinear. 6. T. subulidens, much curved; very slender striæ, strong, few. 7. A smaller specimen. 8. The striation. 9. A straight tooth (the section oval). The striation fine, flexuous, discontinuous. 10. A smaller specimen.

But the slender teeth marked 6 and 7, which are found in a lower jaw of remarkable thinness—in vertical measure—must have belonged to a smaller and more delicate animal. They are for the most part firmly striated, and the striæ deviate but little toward lateral lines (fig. 8), but some are smooth: their figure is awl-shaped, making an approach to the teeth of the gavial, but have little or no trace of the bicarination which is conspicuous in that animal[y]. Fig. 4 represents an unusually-arched tooth, which I refer to the same species, believing it to have held the place of a quasi-canine tooth at the intermaxillary suture. The lateral line with the coalescing striæ is very remarkable (see fig. 5). This species is evidently much allied to that described by Cuvier, which is now called T. Cadomensis.

Finally, the straight or very slightly-arched conical teeth, figs. 9 and 10, remain for consideration. Their cross section is oval; the striæ are fine, somewhat flexuous, and discontinuous. They seem not to be of ichthyosaurian, but may be of plesiosaurian analogies; or, finally, they may be long teeth at the intermaxillary suture, which are sketched in Diagram XLIV. of Teleosaurus brevidens.

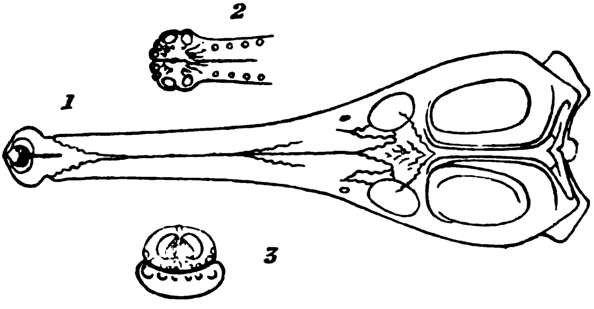

Diagram XLIII. Teleosaurus brevidens. Scale one-tenth of nature.

1. Teleosaurus, upper jaw cranial bones, seen from above. 2. End of jaw seen from within. 3. End of jaw seen from front.

Teleosaurus brevidens, Diagram XLIII.—The length of the head from the occipital condyle to the end of the beak is thirty inches; extreme breadth over the parietal region, ten. Regarded from above, the parietal crest makes a strong division between the large oblong lacunæ, usually called temporal fossæ. In front of these the smaller oval, obliquely-directed orbits are separated by the rhomboidal frontal bone, much pitted, the posterior suture of which enters the orbit. Anterior frontals define a portion of this orbit, and conduct the eye to two small oblong lacunæ or foramina, apparently placed as the nares in plesiosaurus, without however, as far as I see, any so-called lachrymals. Nasal bones, springing from the frontals, advance along the mesial line to a meeting at an acute angle, and then the joined maxillary bones, bearing teeth, succeed, and separate near the end of the beak to admit an enlarged breadth of intermaxillary bones perforated by the external nares (see Diagram XLIII. fig. 1). The nostrils open externally in a nearly-circular hollow at the end of the beak, not, as in steneosaurus, near the end (see Diagram XLV.).

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[y] These teeth agree in their slender shape and feeble carination with those of Teleosaurus Cadomensis. (Cuv. *Ossem. Foss.* t. vii. fig. 10, 11, 12.)

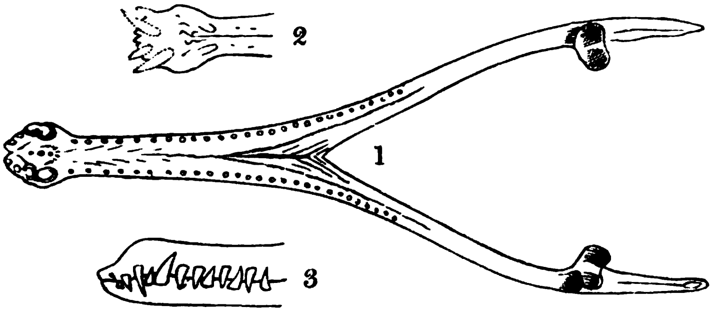

Diagram XLIV. Teleosaurus. Scale one-tenth of nature.

1. Teleosaurus, lower jaw, seen from above. 2. End of jaw seen from above, shewing projecting teeth (incisors and canine). 3. Side of the jaw closed as in nature, shewing the curved junction.

On the under side the palatal surface is nearly plane, the interior nares very far back, much as in the gavial. The pterygoidal bones are seen in a fine specimen of Mr. J. Parker, and resemble those of crocodiles. The articulating faces of the jaws are long, narrow, oval, contracted, and undulated in the middle. Their long axes lie nearly in a horizontal plane, but are directed a little backward, so as to be inclined to the mesial line 80°.

The lower jaw seen from above consists of two curved rami sweeping outward and backward from the long symphysial line, which, however, is not in this species so long as the branches. In the gavial it is longer. The articular bone which terminates the branches is longer than in any other fossil reptile, longer even than in the gavial. It extends more than five inches beyond the condyle. Seen sideways, the bone is formed so as to rest on a flat surface, and it rises gently from near the end to a low coronoid convexity, without the lacuna below which occurs in crocodiles.

The expansion of the branches of the lower jaw is greater in the specimen figured in Diagram XLIV. than is usual. It is the largest complete specimen known to me, and this extreme width, if not occasioned by pressure, may be due to age, as seems to be the case with the Indian gavial. This specimen is 36·2 inches long, of which the symphysial part is 16·7, and the breadth over the condyles 13·7.

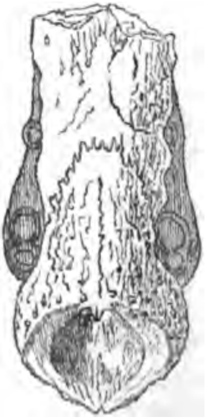

Diagram XLV. Teleosaurus. Scale four-tenths of nature.

The jaws are here viewed from above to shew the almost circular nasal cavity, and the intermaxillary suture, and the lateral prominence of the lower jaw teeth, opposite the diastema of the upper jaw.

The teeth, thirty-one or thirty-two on each side in each jaw, may be characterized as incisors two, separated and directed forward in the lower jaw, close set and tending downward in the upper; captatorial or quasi-canines, two, large, usually only one fully exhibited, the other broken off or fallen out; twenty-seven or twenty-eight nearly similar and of equal size, except the six last, which are smaller and more closely set. The inner pair of the front teeth is occasionally found large. The teeth behind the captatorial pairs spring from narrow tracts much depressed below the general internal floor of the jaw. They point a little forward and are set with the convexity anterior; and of the two faintly-marked carinæ or lines of coalescing striæ, one is posterior and outward, the other anterior and inward. A diastema in each jaw behind the canines. Six teeth in the lower jaw are behind the symphysis; seven or eight in the upper jaw behind the crossing of the maxillary suture.

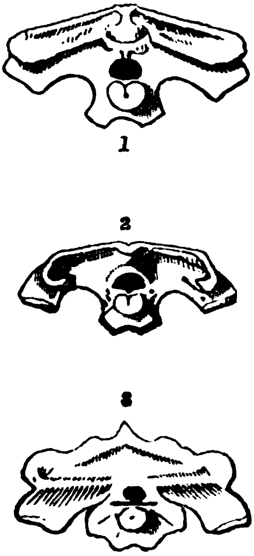

Diagram XLVI. Occipital views. Scale one-tenth of nature.

1. Teleosaurus of Stonesfield and Enslow Bridge. 2. Gavial of the Ganges.
3. Steneosaurus of Shotover from the Kimmeridge clay.

The occipital aspect is represented in fig. 1, Diagram XLVI., in comparison with that of gavial, fig. 2, and steneosaurus, fig. 3. The occipital condyle has a slight vertical groove, as in gavial, not observed in our steneosaurus. The vertebral column is altogether of crocodilian character. The cervicals of teleosaurus found at Enslow Bridge, and represented in Diagram LVIII., in comparison with one of megalosaurus, are of two patterns—once probably belonging to two species. The upper figures (1, 2, 3) represent a more slender form, the lower figures (7, 8, 9) belong to a stouter type; and this distinction is observed in other parts of the column. Both of the articular faces are a little concave, the anterior face least so. The dorsal vertebra, as represented in Diagram XLVII.,

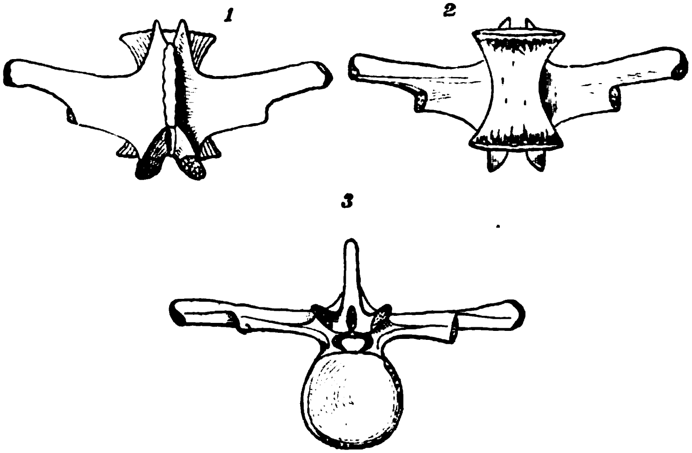

Diagram XLVII. Dorsal vertebræ of Teleosaurus. Scale one-fifth of nature.

1. Seen from above, and looking from the head. 2. Seen from below, looking from the head. 3. In front, as seen from the head.

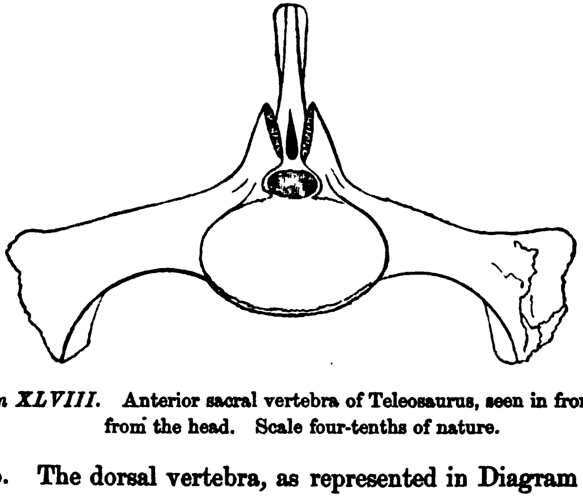

Diagram XLVIII. Anterior sacral vertebra of Teleosaurus, seen in front, looking from the head. Scale four-tenths of nature.

is quite of the crocodilian type. It is the fifth or sixth in the series. The zygapophyses are inclined to each other 60°. The two sacral vertebræ, conjoined almost exactly as in the crocodile (Diagram XLIX.), present transversely elliptical faces of articulation, and zygapophyses inclined to each other only 30° (Diagram XLVIII.).

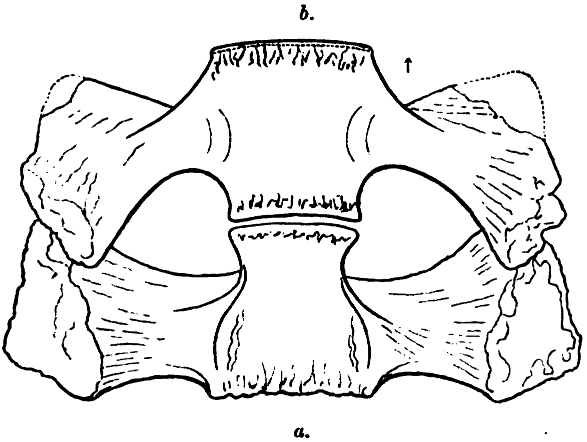

Diagram XLIX. Sacral vertebra of Teleosaurus, seen from above, and looking from the head. Scale four-tenths of nature.

a. Anterior. *b.* Posterior. The arrow points from the head.

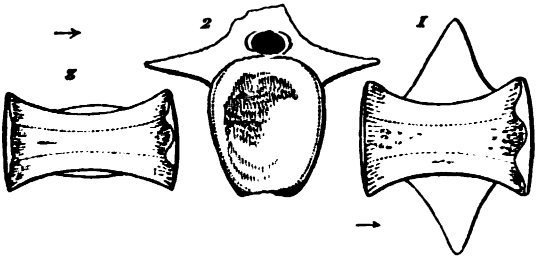

Diagram L. Caudal vertebræ of Teleosaurus. Scale four-tenths of nature.

1. Anterior caudal from below, with the transverse processes large. 2. The same, seen on the anterior face. 3. Posterior caudal, seen from below, without transverse processes, but longitudinal lateral ridges.

The caudal vertebræ (Diagram L.) have their articular faces higher than broad; the anterior caudals have transverse short processes; posterior ones not. Their neural spine, as in crocodiles, becomes more and more elongated and more retral in position, and the corpus is laterally much compressed.

The ribs are of crocodilian type.

Of the pelvic bones we have only the very fine pair of ischia, represented as seen from below in Diagram LI., and a pubic bone, Diagram LII.

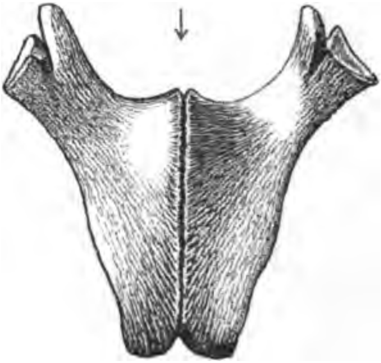

Diagram LI. Teleosaurus of Enslow Rocks. Scale one-fifth of nature.

The ischia in apposition: breadth, seven inches; length about the same; portions of the antero-inferior process broken off.

Ischia.—These bones have plesiosaurian analogy in the breadth of the blade and length of medial connexion, as well as alliance to crocodile in the proximal parts.

The complete specimen here represented helps to explain a figure in the Ossemens Fossiles, Plate XXI. fig. 21, which Cuvier and Buckland admit to be an ischium, and place it with megalosaurus. Professor Owen has given a good (reversed) figure (Mem. Pal. Soc. Plate IV. fig. 5), with bones of megalosaurus, terming it 'right ischium,' but by mistake it is marked as one-fourth of the natural size. It is really half the natural size. The part of the drawing representing the edge is inexact; it was made before the bone was cleared of the matrix. The bone is in the Oxford Museum, and must be referred to teleosaurus.

Pubis.—Specimens of this bone are not common.

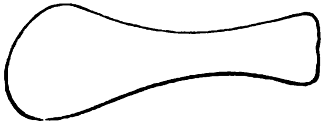

Diagram LII. Pubis of Teleosaurus.

The anterior limb is unknown. Of the posterior we have femora in sufficient number and good preservation. It is, like the corresponding bone in the crocodiles, sigmoidally bent, with a completely-rounded head, which, seen endways, has a rhomboidal outline, with diagonals 2·0 and 1·4. On the inner face a prominent boss, much as in steneosaurus, extends the spheroidal surface of the head. No distinct trochanterial tubercle on the outer and lower part of the bone. Capitular end strongly ridged. The distal extremity is always found to be of compressed form and rounded outline, with but faint marks of the condyles—much as Cuvier represents the bone in the Caen fossil. It is usually eleven inches long, with diameters in the smallest part of 0·9 and 0·7; but some specimens must have been fourteen or fifteen. There is ground for distinguishing two forms; one less sigmoidal, and much more slender toward the distal part of the bone.

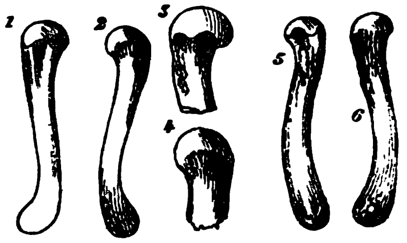

Diagram LIII. Femora. Scale one-tenth of nature.

1. Femur of Teleosaurus, left side, interior. 2. The same, outside. 3. Larger specimen, left side, interior, proximal end. 4. The same, exterior. 5. Femur of Steneosaurus, right side, interior. 6. The same, exterior.

One metatarsal bone in the Oxford collection, 4·5 inches long, is supposed to belong to this species: it indeed closely resembles a middle metatarsal of megalosaurus; but there is not much difference between that genus and crocodiles in the form of this bone.

If the head of this teleosaurus may be taken as one-sixth of the length, we have for its ordinary measure thirty inches, and for the whole animal 180. This would give for the average length of the vertebræ, with the separate cartilage, two inches and a third. The largest nearly-complete specimen of head in Mr. James Parker's collection gives thirty-two inches; and the longest and largest beak in the Oxford Museum indicates thirty-nine inches. Thus the longest animal of which we have traces is 214 inches, = 17 feet 10 inches from the nose to the end of the tail, which is about the size of the largest known crocodiles.

The covering of this teleosaurus was a complete cuirass on the body; some of the scuta nearly rectangular and ridged across, others more rounded, all deeply pitted. They are smooth within (Diagram XLI. figs. 8, 9).

A singular discovery was made some years since, in the Harebushes Quarry, near Cirencester (Great oolite), of a group of oval bodies filled with spar, which were, and I think rightly, judged by Professor Buckman to be eggs of a reptile, and probably of teleosaurus. They are smooth, 1·75 inches long, and 1·0 inch wide[1]. Other eggs, as I think them to be, of the appearance of a thin brown irregularly-inflated tunic, occur at Stonesfield.

TELEOSAURUS SUBULIDENS.

Of this animal we possess a specimen of the very depressed narrow lower jaw, with thirteen very slender awl-shaped teeth, projecting laterally.

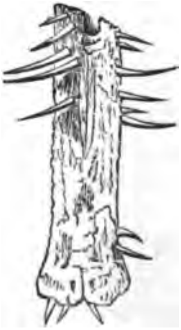

Diagram LIV. End of Lower Jaw of Teleosaurus subulidens. Scale four-tenths of nature.

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[1] Proceedings of the Geological Society, 1859.

We have also a nearly complete lower jaw, wanting the termination; which differs from that of T. brevidens, in its slenderness, being both narrow and shallow, in the greater proportionate length of the symphysis, and in the greater number of the teeth, which are thirty-one on a side, or, allowing four or five for the deficient end, thirty-five or thirty-six, in all 140 or 144. Six teeth behind the symphysis, twenty-five (or twenty-six) to the expanded beak, and four for that part. Eleven slender, and mostly broken, teeth in the sockets appear to be replacing teeth.

The sockets for the teeth are remarkably round, and on the whole nearly equal, and quite large compared to the teeth.

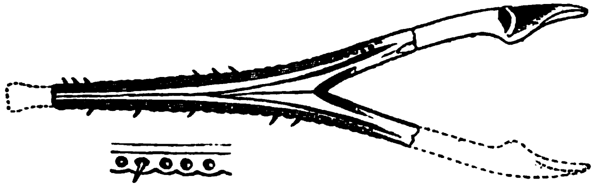

Diagram LV. Lower Jaw of Teleosaurus subulidens. Scale one-tenth of nature.

Of all known fossil reptiles the lower jaw of this small teleosaurus bears the nearest resemblance to that of the Gangetic crocodile, in the essential points of very long symphysis, and numerous long slender teeth. The symphysis is more than half as long as the whole jaw.

The life of teleosaurus may be well judged by the proportions and adaptations of his skeleton and dermal covering. Taking the gavial for comparison, as of similar dimensions, we observe the equally-prolonged jaws for seizing prey, more truly aquatic limbs for steering, and equally powerful tail for swimming. Long, slender, and active, well covered with armour plates, he must have been formidable in the waters even when ichthyosaurs and plesiosaurs were prevalent. These were not prevalent, it appears, in the waters which were much resorted to in this part of the ancient sea. Teleosaurus cannot have so frequently visited the land as the modern crocodiles; and it is in harmony with this conclusion that his remains occur abundantly among the oolitic marine animals, but not in the fluviatile or lacustrine deposits. About eighteen feet may be admitted for the full length, and about half a ton for the full weight of one of the largest of these carnivorous sea-going crocodiles.

MEGALOSAURUS BUCKLANDI.

The remains of this great carnivorous lizard have been found in England at Lyme-Regis and Watchet (lias); near Bridport (Inferior oolite); at Stonesfield (lower part of Great oolite); at Enslow Bridge (upper part of Great oolite and Forest marble beds); at Weymouth (in Oxford clay); at Cowley and Dry-Sandford (coral-rag); at Malton in Yorkshire (coralline oolite); and in Sussex (Wealden). It occurs in Kimmeridge clay at Honfleur in Normandy, and in oolite at Besançon.

The discovery of the nature of these reliquiæ is due to Dr. Buckland's zealous researches among the spolia of the Stonesfield quarries; though it seems probable that some of the specimens in the Oxford Museum were collected before his day. The materials which are preserved at Oxford for a monograph of the animal have been much augmented of late years; and though some of the early determinations, or rather suggestions, of the places in the skeleton of particular bones by Cuvier and Owen have been found to require correction, the main conclusions of the great geologist whose name is associated with megalosaurus remain untouched—one proof among many of the uncommon sagacity of his busy intellect.

Megalosaurus, though not the largest of primæval lizards, has no rival among carnivorous reptiles:—perhaps thirty feet long, capable of free movement on land, with strong but not very massive hind limbs, and reduced fore limbs; a short head, with elevated maxillary bones bearing a few long, smooth, laterally-compressed teeth with regularly-crenulated edges; limb bones which seem to have been hollow within; hind feet of crocodilian type, with strong compressed claw-bones; no dermal scuta.

These characters, considered in detail by help of the University collection and other specimens belonging to Mr. James Parker, in Oxford, to the Duke of Marlborough at Blenheim, and the British Museum, have raised gradually the idea of a peculiar animal essentially reptilian; yet not a ground-crawler, like the alligator, but moving with free steps chiefly, if not solely, on the hind limbs, and claiming a curious analogy, if not some degree of affinity, with the ostrich.

This idea, which is likely to exercise a strong influence on the future study of fossil reptiles, has suggested itself to Professor Owen in considering the peculiar sacrum with its five anchylosed vertebræ[a]: equally firm was the impression on the mind of Professor Huxley when he considered in our Museum the shape of the ilium—formerly conjectured by Cuvier to be a coracoid—and placed in their relative situation the curious slender bones which so closely represent the pubis and ischium of the Struthionidæ. My own convictions had previously tended in the same direction, from considering not the pelvic but the sternal arrangements, when several years since I found the means of completely ascertaining the forms of the scapula and true coracoid, which differ so little from that of the apteryx.

Megalosaurus, then, had avian points of structure, and some of its habits of life were probably influenced by that analogy; but that it was truly of the reptilian type, by the essential arrangement as far as it is known of the head, the vertebral column, ribs, and limbs, we may now proceed to prove.

The head, as it presents itself to my mind after considering the crania of recent lacertians, appears in Diagram LVII., where the parts known are shaded, and the parts conjectured are in outline. The lower jaw is represented in the Oxford Museum by a portion, probably reaching to the anterior end, almost twelve inches long, which space is occupied by a row of nine teeth, or sockets for teeth, Of these, only one rises much above the outer border of the jaw, which is greatly elevated, like a defensive wall. The other teeth must be regarded as destined to replace what had fallen out or decayed. This replacement is very curiously and completely illustrated by three sizes of teeth; quite small below the border, middle-sized, just reaching to or appearing above it, and one great prominent sabre-tooth. The great tooth has its young successor already appearing on the inside opposite the middle, two of the middle-sized teeth are equally provided, and there is one small tooth corresponding to an empty exterior socket.

The upper jaw is known in the Oxford Museum by two portions, each containing the maxillary and intermaxillary bones, the finest and most instructive contributed by Mr. Abbay. The shaded part of the drawing represents this specimen, with several prominent and deeply-rooted curved, compressed, and crenulated teeth in different stages of growth. The length of this maxilla is 17·75 inches; the greatest depth, from what is probably the lateral edge of the nostrils to the alveolar line, 6·75 inches. The tooth at the front edge is 6·4 inches long, the crown being 2·6, and the fang 3·8 inches. The large tooth which succeeds after an interval once occupied by two others, is even of greater size, the crown being 2·7 in length; its fang is also wider, but not so deeply implanted. The other teeth are smaller, and diminish gradually as we go backward, much as in the monitor lizard. The teeth are remarkably curved, with the convexity forward; very much compressed from side to side, and finishing with acute crenulated edges in front and behind (Diagram LVI.). The surface is smooth and polished, the colour usually of a clear brown, the edges quite unworn.

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[a] 'It is this structure, beautifully exemplified in the sacrum of the young Ostrich, which Creative Wisdom adopted to give due strength to the corresponding region of the spine of a gigantic Saurian species, whose mission in this planet had ended probably before that of the Ostrich had begun.'—Reports of British Association, 1841, p. 106.

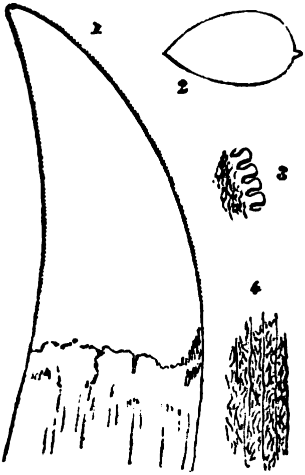

Diagram LVI. Megalosaurus. The Tooth. Natural size.

1. The tooth of megalosaurus, seen laterally. 2. Cross section of the same.
3. Crenulation of the edges where most regular. 4. The finely striated surface.

The grounds on which the restoration of the head has been attempted are stated in the explanation of the Diagram.

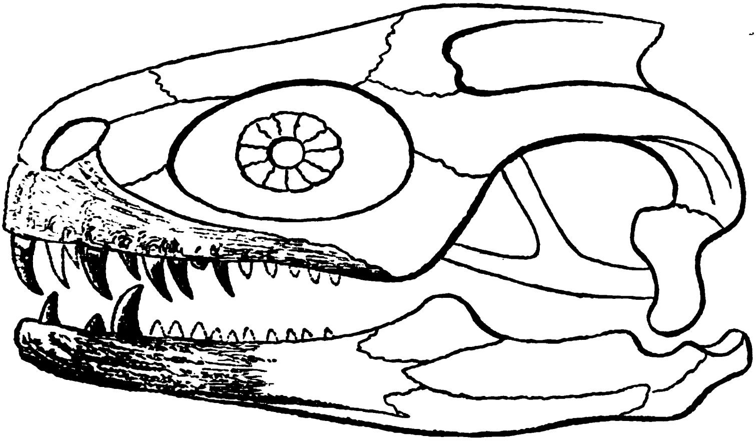

Diagram LVII. Head of Megalosaurus. Scale one-tenth of nature.

Restoration of the head and lower jaw, of which, however, only the anterior portions are known. These are shaded. The type of Varanus is followed in general, but the postorbital arrangement is different, the bony circle there being completed from considering iguana and other lizards with some eye to crocodile. Scale one-tenth of nature. The length of head as thus drawn (thirty-nine inches) is less than that usually allowed (five feet).

The posterior part of the maxillary bone is separated from the orbit, notwithstanding its smooth, apparently free edge, by an intervening continuation of the jugal. This may be objected to. The nasal cavity is supposed to be divided by a median ridge (the single nasal continuous with the intermaxillary bone) into two openings, as in some of the monitors. The intermaxillary bones, which originally included four teeth each, appear united to the maxillary in this adult specimen.

The lower jaw is modelled on the Varanian type, to which more than to any other reptiles the fossils correspond in their serrated teeth. The symphysis was short, the jaw narrow.

Vertebræ of the neck of megalosaurus appear to be rare. We have lately obtained one which is represented four-tenths of the natural size in Diagram No. LVIII., figs. 4, 5, 6, in three aspects, between two sets of corresponding bones of teleosaurus. The body of this vertebra is higher than broad, and about as long as high.

The neural canal small, oval, transverse; the zygapophysial surfaces are oval, plane, and inclined to one another 50°, and placed close above the neural canal. The sides are as it were pressed inward; the prominent surfaces of attachment for the rib are directly over one another, the upper one inclined downward, as in some steneosauri and teleosauri. The lower side, widest anteriorly, is bluntly carinated behind. The articulating faces are slightly concave in the middle, rounded and revolute towards the circumference. The posterior and lower margin projects as if to indicate an upward curve in the neck, as in some mammals and many birds.

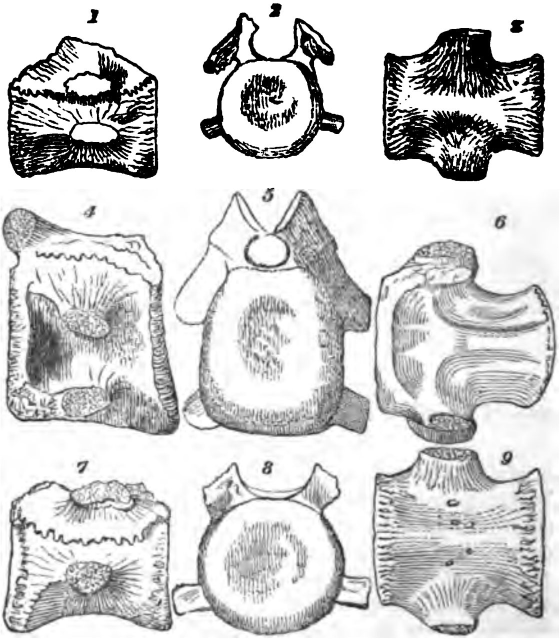

Diagram LVIII. **Cervical Vertebræ of Teleosaurus and Megalosaurus. Scale four-tenths of nature.**

1. Teleosaurus subulidens, seen sideways. 2. The same, seen endways (from the head). 3. The same, seen from below. 4. Megalosaurus seen on the left side; the zygapophysis represented is on the right side. 5. The same, seen endways (from the head). 6. The same, seen from below. 7. Teleosaurus brevidens, seen sideways. 8. The same, seen endways. 9. The same, seen from below.

The dimensions of this vertebra are as follows:—

Length of corpus	2·00 inches	above.
„	2·35 „	below.
Height of articular face . . .	2·20 „	
Breadth of „ . . .	1·85 „	

It will be seen that the vertebræ of the two teleosaurians on the same diagram are longer and more cylindrical.

The anterior dorsal vertebræ of megalosaurus are known by a fine example (probably fourth or fifth) in the Oxford Museum, which was figured by Dr. Buckland (Geol. Trans., Second Series, vol. i. 1824, plate XLII. fig. 2). This lithograph does not express the zygomatic articulations, and some other points of the vertebra, so well as the figure 3 in Diagram LIX., which is taken from the same specimen, but it shews well the great middle contraction of the corpus, and the expanded articular faces. The neural spine is broken off; its probable length is sketched in the diagram referred to. Professor Owen gives in his Monograph of Megalosaurus (Palæont. Soc. Memoirs, 1855) a finished representation of a series of anterior dorsals resembling ours from the Wealden, in which the spinous processes referred to are fourteen inches long.

The Oxford specimen measures 4·5 inches in the length of the body, 4·15 inches from the neural canal to the lower edge of the articular face, and 3·85 across the face, which thus appears a little oval, and higher than broad. The anterior face, though slightly depressed in the middle, is generally convex, and very revolute toward the lower edge. The posterior is more generally but not deeply concave, and also revolute toward the lower edge. The body is very smooth, and so much contracted in the middle in the lower half as to resemble an hour-glass. Above this the upper part rises and expands suddenly, so as to leave a deep longitudinal pit below the suture, which rises to an arch in the middle. The hour-glass or barrel part of the body is 2·5 inches in diameter; the sides of the pit are so pressed in as to be only 1·5 inches apart. The diapophyses and parapophyses are broken, but their bases are traceable. The diapophysial ridge rises obliquely from the edge of the upper part of the posterior face, and has a deep hollow on each side of it.

The anterior zygapophysial process presents a spoon-shaped projection, hollow above and buttressed below, with an expanding mesial hollow dividing the buttress. Into this the posterior zygapophysial process fits by the prominent roof-like base of the neural spine and the grooved triangular buttress below, making a double adaptation (see Diagram LIX. figs. 3, 4, 5). The edges of the zygapophyses are connected by a sort of vertical crest parallel to the axis of the vertebra.

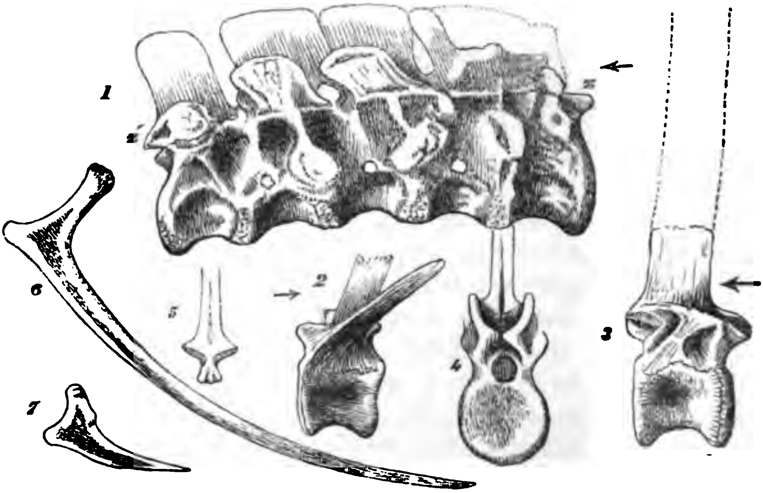

Diagram LIX. Megalosaurus. One-tenth of natural size.

1. Sacrum, seen on the right side. Oxford Museum. 2. Vertebra figured by Dr. Buckland as caudal, seen on the right side. 3. Vertebra—anterior dorsal, seen on the right side. 4. The same, seen on the anterior face. 5. The posterior zygapophysis of the same. 6. Rib—middle dorsal, thirty-four inches. 7. Rib—first or second dorsal, eight inches long.

The arrow in each case is represented as flying from the head.

The upper posterior zygapophysial articulating faces, which look downward and outward, are but little convex, and inclined to each other about 135°; the lower posterior faces (see Diagram LIX. fig. 5), which look upward and inward, are inclined to each other about 45°.

The neural spine, three inches broad, is broken off at 3·5 inches from the base. It was probably fully of the length given in Professor Owen's lithograph (fourteen inches), for the vertebræ shewn in that drawing are not quite so large as ours. The spines are there represented as connate in the upper part, and strongly marked by tendinous attachments.

A larger drawing of this fine vertebra may be useful for comparison with other deinosaurians, and to enable the reader to form a just notion of their relative magnitudes.

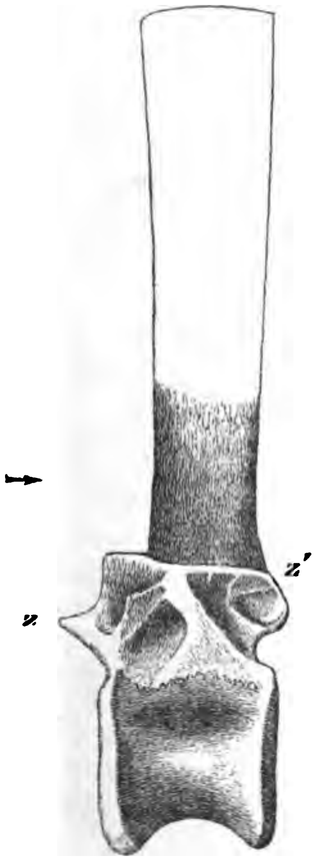

Diagram LX. Anterior dorsal of Megalosaurus, seen on the left side. Scale one-fifth of nature.

z. Anterior. z'. Posterior zygapophysis. The height of the neural spine is uncertain.

The ribs which were attached to the dorsal vertebræ are known by several specimens at Oxford, and by figures of two belonging to anterior dorsals, Cuvier, Ossem. Foss., Plate XXI. figs. 25, 26. These are about eight inches and sixteen inches long, with breadths over the articulating faces of 3·5 and 6·0 inches. In Diagram LIX. fig. 7, one of the short ribs is given on a scale of one-tenth—it is the first or second dorsal. Fig. 6 of the same Diagram represents a middle dorsal rib, thirty-four inches long, with a breadth of 6·5 inches over the two heads of the rib, which is formed in one long curved gradually contracting blade, much narrower and deeper than in crocodiles. One may conjecture that the ribs in megalosaurus being as much lacertian as crocodilian in their blade, though not in their mode of articulation, might exhibit the same mixed analogy in respect of number and be more numerous than in living crocodiles, which have never more than fourteen dorsal vertebræ[b].

Lumbar vertebræ of megalosaurus have reached the Oxford Museum from Stonesfield, one of which, figured by Cuvier and Buckland, was regarded by the latter author as a caudal. In Diagram No. LIX., fig. 2 represents this vertebra seen laterally. Shaped as to the body much as the dorsal already described, its sides are very smooth and deeply hollowed; the suture is lower and less arched than in the dorsal vertebra; the diapophysial spine runs out retrally in an ascending direction (10° from the horizontal) to a length of 5·5 inches from the mesial line, with a breadth of 1·6. The articulating faces are slightly concave in the middle, and revolute toward the lower edge, the anterior face remarkably so. The height of the articular face is 3·5 inches, the breadth 3·7, the length of the body 3·9. The neural canal is contracted in the middle. The neural spine is broken. The base of the diapophysial spine extends along the vertebra between the zygapophysial elements.

In consequence of the revolution toward the lower edges of the articular faces, the interval between these faces is less in the lower than in the upper part.

The Oxford Museum possesses also a larger lumbar vertebra, which resembles so closely the first of the five which are anchylosed to form the sacral, as to deserve the title of last lumbar. The size is rather greater than that of the first sacral. Height of body

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[b] Owen, Reports of British Association, 1841, p. 109.

4·6 inches, length 4·25, breadth 4·5. Elongated cavities are enclosed in this bone, on the sides of the body.

Sacrum (Diagram No. LIX. fig. 1). The five vertebræ which, anchylosed together, constitute the strong support of the hind legs, retain somewhat of the lumbar character in the anterior, and of caudal aspect in the posterior. The neural spines of the second, third, and fourth are united above, separated below: this may also have been the case with the others, and thus a strong continuous vertical crest, twenty-one inches long, completed the fabric. The whole is on a gentle curve, convex upward. The bodies of the vertebræ are deeply constricted in the middle of their length, and thickly annulated by revolution of the articular faces toward the edges. Thus these coalescing edges combine into thick prominent belts measuring an inch across.

These belts rise upwards into strong though short transverse processes, which are placed in a line convex downward, sinking from the first and second toward the third and fourth, and then rising upward to the fifth. The two anterior of these processes are near together, the fourth and fifth far apart. Above them runs a sort of horizontal cornice, formed on the line of the zygapophyses, and above this are vertical arched plates, half as high as the neural spine. Of these, two are very distinct above the third and fourth transverse process: it is not clear whether they did exist in the other corresponding spaces, but as something analogous appears in the dorsal vertebræ, it seems a probable inference.

The anterior zygapophysis is a linguiform projection with a narrow mesial furrow below, and a broad concave receiving surface above. The posterior zygapophysis is shaped to fit this hollow by a broad projecting ledge above a horizontal notch and a narrow triangular prominence. This arrangement is of the deinosaurian type—somewhat like iguanodon—but quite different from that of teleosaurus, or steneosaurus, or living crocodiles.

The neural canal, one inch in diameter, is not contracted in the middle of the vertebræ; it is longitudinally furrowed. Four horizontal tubular passages for nerves lead from the great canal through the three middle vertebræ, and constitute transverse tunnels about five-eighths of an inch in diameter. Three of these, belonging to the second, third, and fourth vertebræ, are open tubes; that corresponding to the first vertebra is filled with stony matter.

The transverse processes of the two anterior vertebræ are broken, and shew cavities in the interior about three-fourths of an inch across; probably the others are similarly constructed. Narrow ridges connect these processes with the cornice on the level of the zygapophyses, having deep hollows on each side. It appears that each of these processes was in contact with the broad ilium which must have sloped away from the sacrum on each side, like a pent-house, as it does in the ostrich (see Diagram No. LXI. fig. 2). The narrowness of the whole pelvic fabric considered in relation to length, height, and tripartite crest of bone, gives a very ornithic aspect to this part of the skeleton. There is no cavity in the body of the vertebræ.

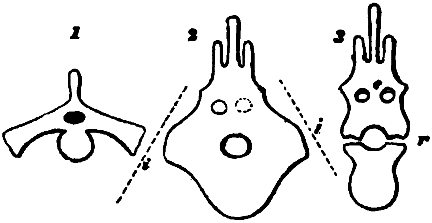

Diagram LXI. Megalosaurus and Teleosaurus. One-tenth of natural size.

Cross sections of the sacral vertebræ.

1. Cross section of sacral vertebra of teleosaurus. 2. Cross section of sacral mass through the fourth (most prominent) transverse process of megalosaurus. 3. Cross section through the middle of a vertebra of megalosaurus, shewing at *r* the passage of a nerve channel, and at *c* inclosed air cavities which lighten the bony mass. They are seen in the first vertebra, and probably exist in the others. *i.* Marks of attachment of the ilium. The dotted lines by fig. 2 indicate the probable outward slopes of the ilia.

The sacral vertebræ have the following lengths, measured below:—

	inches.
First	4·45
Second	4·25
Third	3·90
Fourth	4·25
Fifth	4·45

The height of the anterior face is 4·00 inches, the breadth 3·80. It is distinctly pitted in the middle, and revolute toward the lower margin.

Caudal vertebræ appear to have hardly been observed by the early describers of megalosaurus, that so called by Buckland being clearly lumbar. Several caudals much compressed laterally come to us from Stonesfield and Enslow Bridge, which I regard as teleosaurian. One specimen, two inches long and broad, two and a half high, the articulating faces equally concave, with sides compressed below the transverse processes, appears to have belonged to the anterior part of the tail of megalosaurus. The neural processes are wanting, and the specimen is obliquely compressed. This vertebra is represented in Diagram LXII.

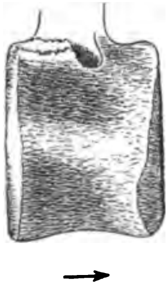

Diagram LXII. Side view of a caudal vertebra of megalosaurus, from Stonesfield. The arrow points from the head. Scale four-tenths of nature.

The 'fore-quarter' of this animal, including in this term the scapula, is known only to the extremity, and barely to that, of the humerus. No trace of the middle element of the shoulder girdle is known; what was regarded by Buckland as a clavicle[c], appears by later research to be probably an ischial bone; what was once admitted on the authority of Cuvier to be a huge lacertian coracoid, is found to be, as Buckland originally believed[d], an ilial bone; and the true coracoid, a smaller and simpler plate, is anchylosed to the scapula, and forms with it the glenoid cavity[e].

In Diagram LXIII. the scapula, coracoid, and humerus are seen in apposition on the left side of the animal. The scapula was known to Professor Owen, but in a fragmentary state, in the Bucklandian collection, and is described in his Report on Reptiles as a 'thin slightly-bent plate, of equal breadth except where it is expanded and thickened towards the humeral end, but thinning off again towards the articular margin.'

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[c] Ossemens Fossiles, tome v. part 2, p. 347, ed. 1824.

[d] Geol. Trans.

[e] Letter from Professor Phillips to Professor Huxley, Geol. Proc. 1869.

There are in reality two forms of scapulæ in the Oxford collection placed in the megalosaurian series, one of which is anchylosed to the coracoid, the other not so. They differ enough to be certainly referable to different species of animals, the second mentioned being of larger size. In the first the thin broad blade, thickest behind, has subparallel curved, rather undulated edges, is a little bent on itself, somewhat contracted and thickened toward the lower part to a kind of neck, from whence expanding to nearly twice that contracted width, it is rounded in front, concave retrally, and undulated

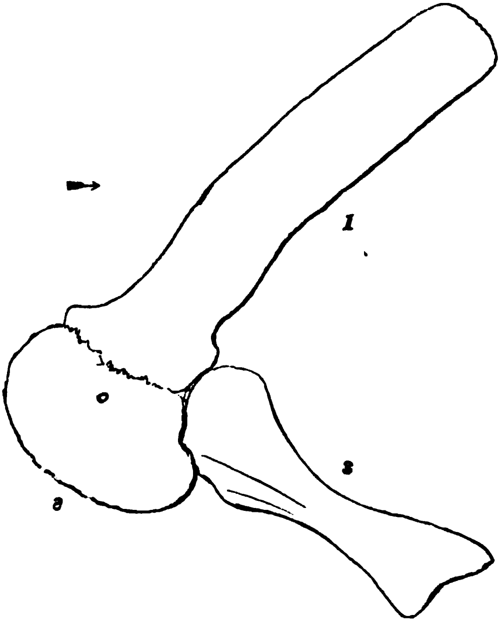

Diagram LXIII. Megalosaurus. Scale one-tenth of nature.

The left aspect of the shoulder girdle is here restored in outline from specimens in the Oxford Museum, which are complete except in regard to the lower end of the humerus. It will be remarked how bird-like in the general arrangement and the forms of the bones is the humero-scapular structure, and specially how closely it resembles Apteryx.

1. Scapula. 2. Coracoid. 3. Humerus.

along the thickened border which connects it with the coracoid. Length twenty-seven inches, breadth of blade in the middle five inches, at the base ten inches.

The coracoid is generally oval along all its free edge, nearly straight but undulated in its junction with the scapula, emarginate at the posterior edge to receive the humerus. The surface is nearly plane, with a perforation in the middle of the breadth, near the upper edge. Length twelve inches, height seven.

The other kind of scapula from Stonesfield is similarly bent like the stave of a barrel, and has subparallel edges; the breadth, nowhere less than seven inches, enlarges toward the upper part, where it is broken off, contracts below to a sort of neck, and then expands in a thick plate to a breadth of thirteen inches. The whole length of the fragment is twenty-four inches. In the lower part, behind the middle of the coracoidian edge, it is deeply and rather obliquely grooved, in this somewhat resembling the corresponding bone of iguanodon figured by Professor Owen (Wealden Fossils, Memoirs of Palæont. Soc., Plate XIV.), from Rusper in Sussex. The groove, however, in that bone is represented much nearer the posterior edge, and the lower margin is more boldly undulated. It is of nearly double the breadth of the bone figured by Owen, which was 22·8 inches long. No coracoid is known which might correspond with this bone.

Of the humerus we have two specimens, neither complete; but one shews the proximal extremity, the contracted shank, and a considerable part of the distal expansion; the other assists to complete the analogy of the bone with the humerus of a crocodile, which is allied to that of a bird. Bone hollow—internally.

The broad strong arched plate of the ilium is narrowed in front, and ends with a double truncated keel, or rather bearing internally an elevated short keel; retrally it is broader; from both ends the lower margin returns to inward curves, and then projects in thick strong processes which receive the pubic and ischial bones. These appear to have been joined in the lower part of the acetabular socket, which probably was perforated at the side. This arrangement of the pelvis, which resembles that of a bird, or monitor, and not that of a crocodile, was suggested by Professor Huxley, to whom I mentioned the perplexity caused by the long sigmoidal bone, which Buckland had believed to be a clavicle, and Cuvier conjectured to be a fibula.

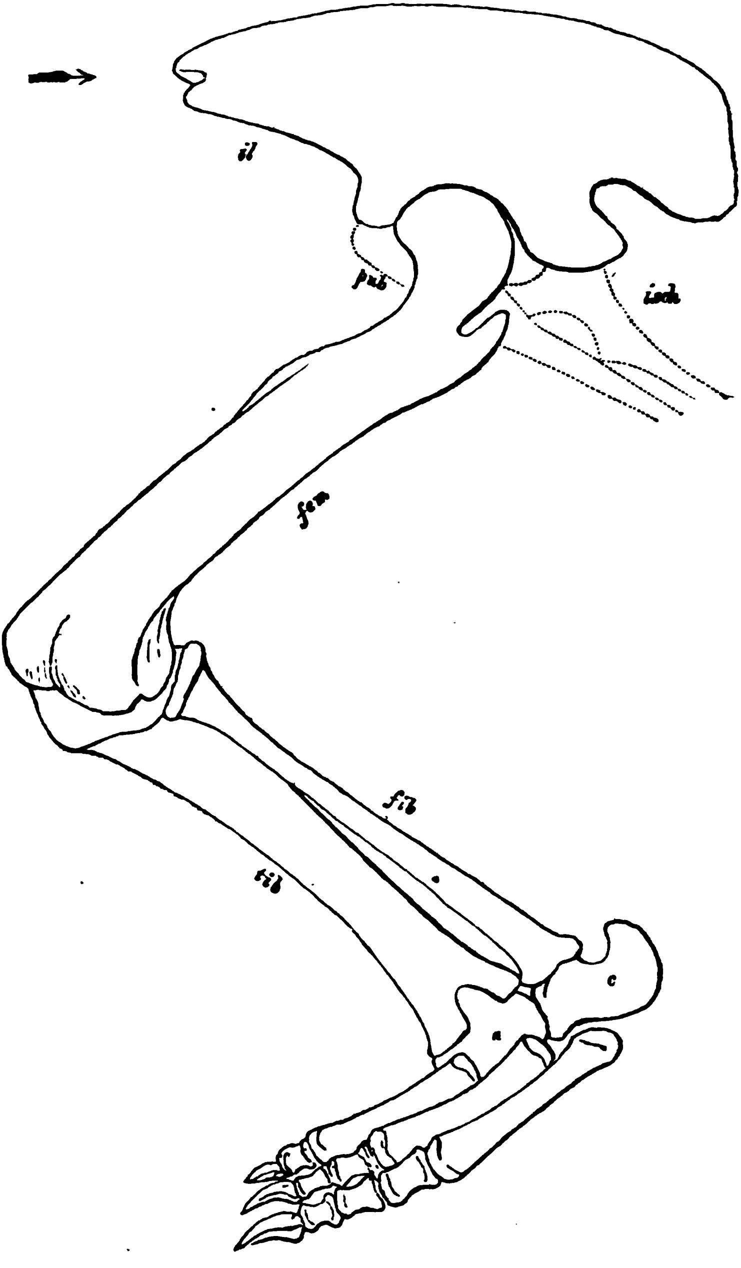

Diagram LXIV. Megalosaurus—hind leg. Scale one-tenth of nature.

This restoration in outline of the left hind limb of Megalosaurus is drawn from specimens, with the exception of the fibula, calcaneum, and ordinary phalangal bones —the claw-bone is known. Dotted lines represent the probable position of the pubic and ischial bones (according to the view of Professor Huxley); these being preserved in the British Museum and in the collections of the University of Oxford.

The principal bones are marked:—il. = ilium, pub. = pubis, isch. = ischium, fem. = femur, tib. = tibia, fib. = fibula, c. = calcaneum, a. = astragalus. Cuvier supposed the calcaneum to be smaller than here represented.

Ischium. This is the long doubly-bent bone represented in Diagram LXV., which was regarded as a clavicle, but by comparison with specimens of iguanodon and skeletons of struthious birds, has acquired quite a new meaning in the hands of Professor Huxley. The Oxford Museum contains one nearly complete specimen and a portion of another. The bone met the prominent part of the ilium behind the acetabular socket, by its bulky head which retains marks of the adherence. A sharp and very prominent keel rising much above the general surface passes in a half spiral along the bone. Length twenty-four inches.

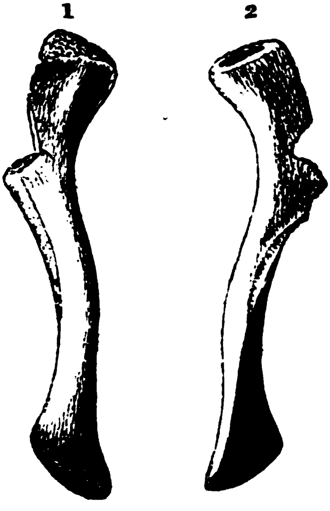

Diagram LXV. **Ischium of Megalosaurus. Scale one-tenth of nature.**

1. External view, right side. 2. Internal view, shewing the oblique symphysis.

Pubis. This slightly-curved, slender, and comparatively simple long bone (Diagram LXVI.) has been usually regarded as a fibula;

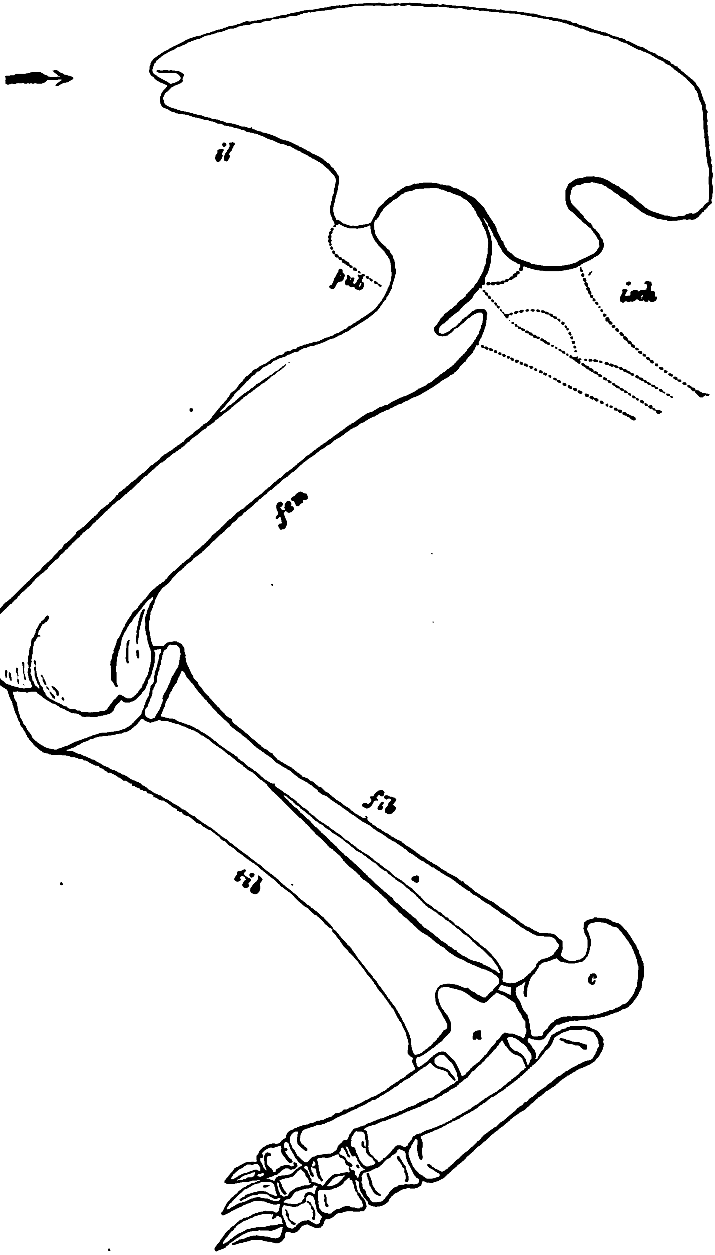

Diagram LXIV. **Megalosaurus—hind leg. Scale one-tenth of nature.**

This restoration in outline of the left hind limb of Megalosaurus is drawn from specimens, with the exception of the fibula, calcaneum, and ordinary phalangal bones —the claw-bone is known. Dotted lines represent the probable position of the pubic and ischial bones (according to the view of Professor Huxley); these being preserved in the British Museum and in the collections of the University of Oxford.

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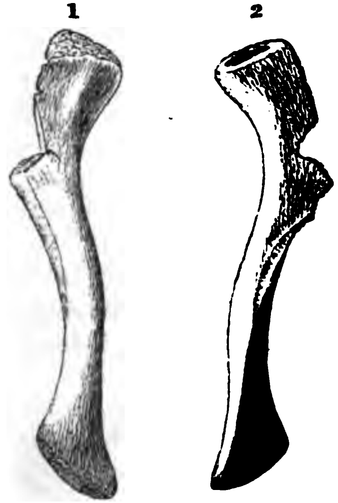

Diagram LXV. Ischium of Megalosaurus. Scale one-tenth of nature.

1. External view, right side. 2. Internal view, shewing the oblique symphysis.

Pubis. This slightly-curved, slender, and comparatively simple long bone (Diagram LXVI.) has been usually regarded as a fibula;

but on the view that the sigmoidal bone is a struthious ischium, this should probably be rightly regarded as a pubis with similar affinities. Length twenty-four inches.

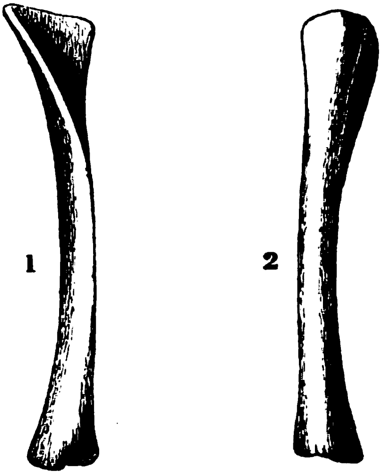

Diagram LXVI. Pubis of Megalosaurus. Scale one-tenth of nature.
1, 2. The specimen is seen in opposite directions, and placed as if it had been vertical, which was probably not the case.

As in the ischium, so in this, a curious, half spiral, very prominent keel begins near the proximal end, and subsides toward the distal end.

There is a second ilium of quite a different form in the Oxford Museum, represented in Diagram LXVI. It is 4·25 inches long, and 1·8 high, the diameter of the acetabular socket 1·25. The

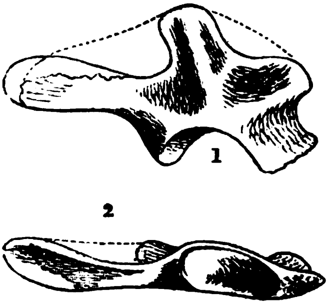

Diagram LXVII. The small ilium from Stonesfield. Scale one-fifth of nature.
1. External view. 2. To shew the acetabular socket.

posterior or ischial protuberance 0·8 in. long, the pubic protuberance of very small extent. The anterior part runs out into an oval blade, externally plane, internally bearing a high median crest. Over the acetabulum rises a thin broad plate with two large external ridges directed to two excurrent prominences. The internal surface of the broad plate is nearly plane, and marked by attachment of vertebræ. The acetabulum is somewhat oblique, half oval in outline, and quite open below.

It more resembles the ilium of iguanodon than of megalosaurus. Perhaps, however, it may be thought to be the bone of a young megalosaur, of one or other of two species indicated by the scapulæ, because another specimen about four times as large presents some trace of a corresponding form. The dotted outline in the diagram represents the change which must have occurred in the course of growth, if this conjecture be allowed. The outline of the specimen depends on Dr. Buckland's apparently careful completion with plaster, and it is possible that in the depth of the undulations there may be some error. The old specimens differ somewhat in outline.

The femur is in general of a crocodilian type. The length of the longest complete specimen at Oxford is 33·5 inches[f].

It is more curved than in iguanodon, but not nearly so much as in teleosaurus and steneosaurus. The head is more spheroidal than in crocodile, and less impressed laterally; it has a faintly-marked flattened or concave transverse space or neck, like ceteosaurus, and projects forwards and inwards more from the general line of the bone than in crocodiles, teleosaurus, and steneosaurus. The great trochanter rises into a large free process, much more prominent than in ceteosaurus, but less styliform than in iguanodon. On the inner edge, about one-third down the bone, the lesser trochanter rises in a prominent crest about six inches in length.

The condyles are recurved and separated by a deep hollow behind; and they occupy, in the largest specimen, a breadth of 8·4 inches; on the outside is a sort of pulley mark for the head of the fibula.

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[f] We possess other large femoral bones; one, incomplete at the head, must have reached thirty-six inches; a third, of which the middle part is lost, is of much greater size, so as to be computed at forty-two inches when perfect. The former was found in 1869 at Enslow rocks with ceteosaurus. The latter may have been obtained from the same locality; it seems not unlikely to be of a different genus, judging from the extremities only.

In the large femur from Enslow rocks we may take the length, when complete, at thirty-six inches; at thirteen inches down the bone the lesser trochanter begins, and it extends six inches.

The femur is, or appears to be, internally hollow, quite clear of structure like a bird's bone.

The tibia of megalosaurus is shorter than the femur in the proportion of twenty-seven inches to thirty-three; it is compressed, especially in the distal half, and has in the upper part, in front, a prominent procnemial ridge, somewhat like that of a struthious bird. On the outer edge, one-fourth of the length downward, is a rough exocnemial crest for the coherence of the fibula. The head of the bone is longer than broad, oval in outline, and narrowed toward the procnemial crest. It is somewhat depressed across, and has on the outward edge the marks of the attached fibula.

Viewed in its general relations, the tibia appears a nearly straight bone; it is, however, in a certain degree twisted, being much compressed from front to back in the lower part, and in a less degree from side to side in the upper part. If it be viewed lengthways, the articular ends lie in such a manner that their outlines cross one another nearly at right angles, as Professor Huxley has remarked.

The lower end of the tibia is peculiar in the mode of articulation with the astragalus. For that bone, instead of being as usual partly posterior, and occupying the whole breadth of the tibia, rises upward in front in a broad flat plate, which fits to a well-defined hollow on the flattened face. Its extension toward the fibula is cut off in that direction by a nearly vertical surface, which is marked by the attachment of the calcaneum, as Cuvier observed on a specimen from Honfleur (Ossem. Fossiles, Plate XXI. fig. 35).

On comparing this bone with that of a crocodile, several differences appear. In that animal the proximal tibial articulation, including the fibular head, makes a transversely oval surface, the outline slightly excurrent in front, of the same breadth as the femoral condyles, and with only a trace of procnemial ridge. The fibula is not attached to the tibia except at the upper edge; the lower end is convex in front, and much concave behind. The astragalus projects behind, and rises there to a broad articulation with the interior condyle. If these bones of megalosaurus were turned round 180°, they would more resemble the arrangement in the crocodile than in the position now assigned to them. The proximal and distal extremities of the tibia in the crocodile have their long diameters divergent about 45°, instead of being nearly at right angles as in megalosaurus.

The fibula of megalosaurus is not sufficiently known, but it must have resembled that of iguanodon, with its distal articulation confined to the calcaneum.

The hind foot of megalosaurus is known only in respect of the astragalus (already described), metatarsals, and ungual phalanges. In the restoration (Diagram LXIV.) I have added, conjecturally, the remaining phalanges and calcaneum, trusting to the crocodilian analogy of the whole. What were the bones of the tarsus, and whether there were or were not a fourth toe, I have no knowledge. Three metatarsals in the Oxford Museum, apparently of megalosaurus, lying together in their original apposition, have been obtained from the Kimmeridge clay of Swindon, and seem to indicate a tridactyle foot (Diagram LXVIII. fig. 1); several long detached bones of the same general form have been obtained from

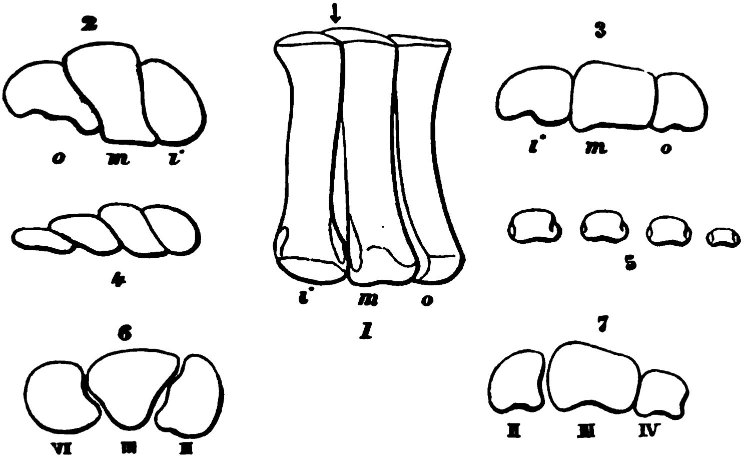

Diagram LXVIII. Metatarsal Bones of Megalosaurus, with additional illustrations. Scale one-tenth of nature.

1. Three metatarsals in apposition, from Swindon, which appear to be megalosaurian. 2. The appearance of these at the proximal end. 3. The appearance at the distal end. 4. The appearance of the corresponding bones in the crocodile at the proximal end. 5. The appearance of the same at the distal end. 6. Iguanodon, proximal ends of metatarsals. 7. The same seen at the distal end.

Stonesfield since Cuvier figured a fragment (Ossemens Fossiles, Plate XXI. fig. 20) under the title of humerus; Buckland, however, having rightly named it metatarsal (Diagram LXIX).

The specimens available for study are three, as already said, from the Kimmeridge clay of Swindon; four from Stonesfield, one of them complete; a fine distal extremity marked 'Enstone,' but supposed to be from Enslow Bridge. The Swindon specimens seem to be a complete series of the left foot. Those of Stonesfield and Enstone (or Enslow) give evidence of three toes, and they are the same as the three found near Swindon. Marking them i, m, o (inner, middle, outer metatarsals), we find two distal articulations of the first with parts of the shanks, of the same side as the specimen from Swindon; one complete bone of the second, of the opposite side; one distal end of the third, corresponding with that just named. There is also an imperfect proximal end with part of the shank. When these are compared with the foot-bones of iguanodon, discovered by Beckley, and described by Owen (Pal. Soc., Wealden Reptiles, 1856), they seem to be representatives, and especially the distal articulations correspond. These foot-bones are regarded by Owen as belonging to the second, third, and fourth toes, and there is said to be a trace of the first attached to the second metatarsal. In a very large specimen in the British Museum this trace does not appear.

These bones sometimes appear as if they had been originally completely hollow, within a compact exterior substance; but even when the central parts are filled by calcareous spar, traces of cellular tissue appear: in other cases nearly the whole of the central parts are largely cellular. They much resemble the corresponding bones of crocodiles, and have well-defined faces of articulation, which indicate free movement of the toes in a vertical sense (Diagram No. LXIX.).

A perfect specimen from Stonesfield of what appears to be the second metatarsal, which agrees with the middle of the three from Swindon, is measured as follows:—

	inches.
Length	13·2
Breadth of proximal extremity	2·40
Height of the same	4·25
Least circumference near the distal end . .	5·80
Breadth of distal extremity	3·10

	inches.
Height of the same	2·50
Radius of curvature of the distal articulation .	1·35
Arc intercepted	180°·0
Chord of this arc inclined to the axis of the bone .	70°·0

The ungual bone appears in a very compressed form, with a length of four inches, and a height of 1·9 (Diagram No. LXIX). The surface is grooved for the attachment of the horny claw; the articulating face is like that of the crocodile, but rather more arched, and much higher and narrower in proportion.

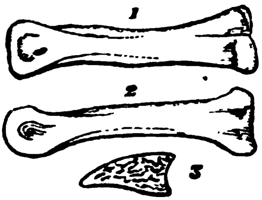

Diagram LXIX. Middle metatarsal of megalosaurus, one-tenth of natural size.
1. Seen from above. 2. Seen laterally. 3. The claw-bone.

What may be regarded as the family affinity and personal history of Megalosaurus Bucklandi has become much more interesting, and even important, in science than it was in the days of its discoverer. The creature was a lizard allied to crocodile in his vertebral system and the general character of his respiratory structure; claiming kindred with the monitors in his dentition; and offering analogy with pedestrian birds in the scapular and pelvic girdles, and to some extent in the limbs. He was carnivorous, if we may trust the finely-crenulated sabre-like teeth, and the large and powerful hinder claws.

He was habitually able, and probably preferred, to move upon the land—whether bipedally is not ascertained, though the fore limbs appear to have been only half as long as the strong yet not clumsy hind legs. These appear, by the enormous ilium, to have been well devised for firmly supporting and propelling the body. The remains are found scattered in a lagoon or shallow estuary, and it is conceivable that the fishes which abounded in that water were the favoured food of the carnivorous reptile. One seems to behold him wading by his long legs, or swimming by help of the tail, a gigantic triton among not inconsiderable cephalopods, whose tough muscles he shared with the frequent voracious sharks; at other times he may have been content with the spare diet of marsupial quadrupeds which lived on the borders of the water. It is perhaps worthy of remark that the teeth are very little or not at all worn, even toward the point; they seem to have fallen easily out of their incompletely-separated sockets, which are almost united into a long groove, and to have been replaced by several renewals, so that he was as well supplied with weapons as the sharks, with whom, probably, he was not on good terms.

The mixed zoological relationships which are discovered by examination of the bones, offer curious and tempting problems to the comparative anatomist. What is known of the succession of life-forms in geological periods is enough to assure us that, in every class, in many orders, and in some families and even genera, there is evidence of gradual substitution of one later form for another earlier, without, as far as is known, any recurrence to a former stage. If we tread back those steps, we are led into no labyrinth, or workshop in which Nature is found trying her 'prentice hand;' we are stopped; there is no further progress; the form is lost; other and earlier races appear, of which these have taken the place[g].

The steps backward and forward of megalosaurus are few: the lias, oolites, and wealden are the limits of his race. If we include all his kindred—all the deinosaurs—their pedigree ascends only to the midst of the poikilitic rocks, where they first appear associated with a widely different group of reptiles which can be traced far backward through many steps, but not any in the forward direction. Among the earliest reptiles closely allied to megalosaurus may be noted teratosaurus of the Keüper, of which fine portions in the British Museum might be mistaken for their later relative.

The lengths of the head, body, and tail of megalosaurus have been separately estimated by Professor Owen in his Report on Fossil Reptiles (1841, p. 109), as follows:—

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[g] 'Augescunt aliæ gentes, aliæ minuuntur,
Inque brevi spatio mutantur sæcla animantum
Et, quasi cursores, vitaï lampada tradunt.'
LUCRET. ii. 76.

	ft.	in.		
Head	5	0		
Trunk, with sacrum	9	7	7 16	Cervical vertebræ. Trunk vertebræ.
Sacrum	1	10	5	Vertebræ.
Tail	12	6	36	Vertebræ.
	28	11	64	

In this computation it now appears probable that too great a length is assigned to the head and neck; on the other hand, taking the maximum number in crocodiles, perhaps the vertebræ might be counted to sixty-eight, and thus the general result would be not materially varied. I am disposed to think the length rarely exceeded twenty-five feet. If the analogy to the monitors were followed, the tail might be very much longer. The weight of the animal must have reached two or three tons.

RHAMPHORHYNCHUS BUCKLANDI.

It was not only by great size that the class of reptiles maintained their pre-eminence in former times; still more remarkable were they for varied and singular forms which are without living parallels. The race now to be considered were flyers, but not by means of extended ribs, like the modern lizards called dragons; nor by feathered wings without distinct digital bones, as birds; nor by self-folding membranes stretched on elongated fingers, like bats. Their flying organs were supported on a single wing-finger terminated by a long pointed bone, while the other fingers were short and bore hooked claws. With their long neck and bird-like beak, these aërial creatures seem hardly to be genuine reptiles, but have that heteroclite aspect which in some biological speculations has been readily admitted for the past periods of the earth's history, though resolutely refused for the present.

Fresh from the study of megalosaurus, whose structure and functions in life made some considerable approach to the almost wingless struthionidæ, we see in the pterodactylians, on the contrary, forms imitative of birds which, like the albatross, pelecanidæ, and terns, have superior powers of flight sustained by wings of unusual length. Well might Cuvier, some of whose thoughts we are here unfolding, conclude that of all the strange beings which were made known by geological research, these were the most extraordinary; and could they be now seen alive would appear anomalies, if not monsters, in nature.

The group of pterosaurians includes more than the three best known genera, entitled dimorphodon, rhamphorhynchus, and pterodactylus; the first being found in the lias, the next not infrequent at some places in the oolites, the third abundant at particular localities in the cretaceous strata. Of these only rhamphorhynchus is known in the oolitic district round Oxford, and it is found almost only at and near Stonesfield; the exception being at St. Clement's, in the Oxford clay, as will be noted hereafter.

The title of Pterodactylus Bucklandi has commonly been given to these remains, by authority of Goldfuss; but Dr. Buckland did not specially describe the bones of which he had mainly been the discoverer, though his sagacious observation was fully employed on the older liassic forms now called dimorphodon. Nor was the want supplied by any naturalist till, in 1859, Professor Huxley prepared descriptions and figures of most of the various fragments which had been obtained, chiefly from Stonesfield, by different collectors[h].

The Oxford collection contains specimens of most of the bones required for a full understanding of the skeleton of rhamphorhynchus, but the exceptions, if few, are very important. We have no fragments even of the cranium or of the upper or lower jaw. A fine specimen, the anterior portion of the lower jaw, was obtained not from Stonesfield, but from a quarry at Sarsden, called Smith's Quarry, in strata of the Stonesfield series. It is in the possession of Earl Ducie. Three other specimens of the lower jaw have been seen: one was brought from Stonesfield by Mr. Beckles in 1860; another is in the British Museum; a third was in the private collection of Professor Quekett. We are without trace, at Stonesfield, of the sternum, dorsal or caudal vertebræ; and no bone has been found to indicate the pelvic arrangement.

These defects can be to some extent remedied by help of the skeletons of dimorphodon in the lias, and pterodactylus in the cretaceous rocks; for other parts of the bony fabric we have considerable if not complete materials of study.

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[h] Proceedings of the Geol. Soc., vol. xv. p. 658.

After frequently examining the numerous bones in the Oxford Museum, and considering the restorations of Goldfuss, Buckland, and Owen which represent allied genera, the idea which rises to my mind of the external aspect of Rhamphorhynchus Bucklandi is presented above. It is much more like a bird than are any of the drawings referred to, which, as already observed, are restorations of other and less decidedly flying animals.

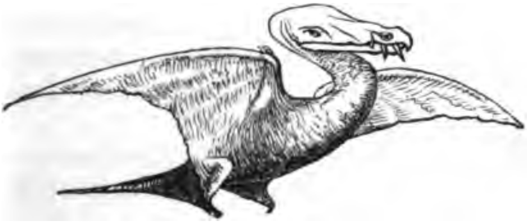

Diagram LXX. Rhamphorhynchus Bucklandi.

The mandible, of which four examples are known, is represented in Diagram LXXI.

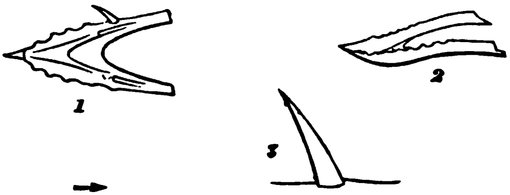

Diagram LXXI. Rhamphorhynchus Bucklandi. Scale one-fifth of nature.

1. Mandible, seen from above. 2. The same, seen sideways.
3. One tooth of natural size.

In a general view, it has a certain resemblance to the lower jaw of plesiosaurus; a short symphysis uniting slender rami, and bearing anteriorly a few sockets for prominent acute, nearly straight conical teeth. The extremity runs out into a kind of beak (fig. 1), with a certain space on each side of it without traces of teeth. Sockets for teeth, apparently of similar size, are observed along the rami for above two-thirds of the whole length, after which the jaw is edentulous (figs. 1 and 2).

The side profile of the jaw shews nearly parallel boundaries, the whole formed on a curve, convex upward behind, convex downward in front. There is no elevated coronoid process, and only a gentle rising in front of the articulation. The two rami are anchylosed together in Lord Ducie's specimen, in other cases they have been separated. In the cross section the outer margin is raised higher than the inner. In these particulars it somewhat resembles plesiosaurus. The composition of the jaw is not clearly traceable, owing to ossification.

Length of the specimen in Mr. Quekett's collection 4·75 inches, greatest depth 0·5. Judging by the specimens of Dimorphodon macronyx, this should give the cranium and upper jaw a length of fully five inches; which is much less than the corresponding measure in dimorphodon, whose wing-bones are only two-thirds as long as those of rhamphorhynchus. Rhamphorhynchus thus appears to have had very different proportions from those of dimorphodon—a smaller head and longer wings.

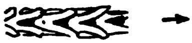

Diagram LXXII. Vertebræ of Rhamphorhynchus. Scale one-fifth of nature.

The cervical vertebræ of the Stonesfield fossil are not completely cleared in our specimens: their length is 0·75 inch; so that allowing for the small atlas and cartilage, we should have somewhat about five inches for the cervical region, which agrees with the measure of dimorphodon.

We come now to the shoulder girdle, of which we know only the scapula and coracoid represented in Diagram LXXIII. These are almost identical with the parts bearing the same name in dimorphodon.

The scapula is a long, narrow, arched plate, thin and sharp-edged in the upper or free part, growing thicker toward the point of union with the coracoid. This union is by synostosis; at least three specimens agree in having the bones united, though in two others they are separated. Length of the largest, three inches.

The coracoid is smaller, shorter and straighter, narrow toward the sternum, widening and thickening toward the scapula, where it makes a small part of the glenoid cavity. The drawing represents the interior aspect of these bones, and shows only, by the sort of notch near the proximal end of the scapula, the mark of the glenoid cavity.

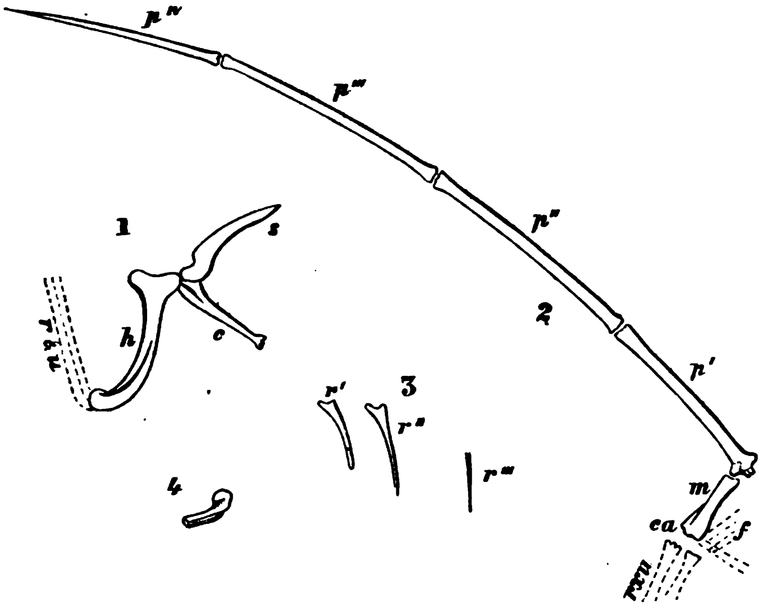

Diagram LXXIII. Rhamphorhynchus Bucklandi. Scale one-fifth of nature.

1. The shoulder girdle: *s.* Scapula. *c.* Coracoid. *h.* Humerus. *r.* and *u.* Radius and ulna. 2. The wing-finger: *r.* and *u.* as before. *ca.* Place of carpus. *f.* Small fingers. *m.* Large external metacarpus, followed by p^{i}. first; p^{ii}. second; p^{iii}. third; and p^{iv}. fourth phalanx. 3. Ribs: r^{i}. r^{ii}. and r^{iii}. in order of position. 4. Curved bone, conjecturally mentioned as clavicle.

There is no known clavicle for any of the pterosaurians. In the course of examining a great number of bones I have found the small peculiar arched bone represented in Diagram LXXIII. fig. 4, which appears sufficiently like the clavicle of plesiosaurus to raise a conjecture of its being really homologous. Length 0·9 inch.

The coraco-scapular bone supports a curiously-bent strong humerus, with a broad furcate proximal head. The drawing is made from a specimen shewing the interior face. Length 4·6 inches; breadth of proximal end 1·5.

Two long, slender, somewhat curved bones in the Oxford collection, which do not correspond to any other of the long bones, may probably be bones of the fore-arm—radius and ulna—of different individuals. Length of one 4·5 inches; of the other 5·0. Not being able to develope the condyles, so as to be quite satisfied of their true character, only dotted lines are added in the Diagram to indicate their supposed place in the skeleton. Their distal extremities are enlarged, so as, in unison, to make a complicated articulation with the carpus.

No carpal bones have been discovered.

Only one example of the metacarpal of the wing-finger is known. It is in the possession of Dr. Wright (*m.* fig. 2). This is a short strong bone, widest at the proximal end, and furnished with a double condyle at the distal end. Length two inches.

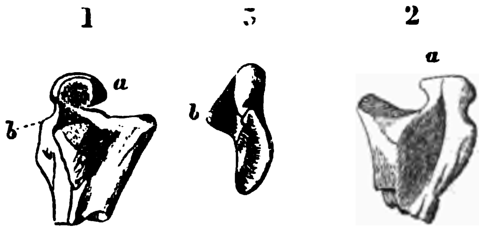

Diagram LXXIV. Proximal condyle of first phalanx of wing-finger of Rhamphorhynchus Bucklandi, in three aspects. Scale size of nature.

a. and *b.* mark corresponding points in three views.

Next follows the first phalanx of the wing-finger (*p′*), bent and angular in the proximal part, thence nearly straight and flattened. The proximal end articulates with the condyles of the metacarpal, something after the manner of the junction of ulna and humerus; the distal end is expanded and obliquely truncated. Length 5 inches; smallest diameter of the shaft 0·3.

The proximal condyle, which appears clear in one specimen at Oxford, is represented in Diagram LXXIV.

The second wing-finger (*p″*) attains in one example a length of 7·75 inches; and, somewhat widened by compression, a breadth of

0·4 in the smallest part. The proximal end is widened to 0·8; the distal end measures 0·5.

The third wing-finger joint (p^{iii}) is of equal length, but only 0·25 inches in the narrowest part, widened proximally to 0·53, distally to 0·4.

The fourth phalanx (p^{iv}) is a very slender bone, which from the proximal end proceeds straight for about two-thirds of the length, and then bends inward. The bone is like a long curved awl, beginning with an articulating face 0·35 inch broad, from which it contracts by a curve on the inner face, and then proceeds by a continual tapering to a fine rounded termination. Length 6·5 inches.

All the bones which have been mentioned are smooth and polished on the surface; they were all hollow in the parts having any considerable diameter; and in most cases they have yielded to compression, so as to present longitudinal grooves, as well as a very elliptical section. They were originally of a compressed figure, the greatest diameter of the finger-bones being parallel to the greatest width of the articulating faces.

The substance of the bones is traversed lengthways by Haversian canals, and dotted everywhere with lacunæ of various figures, with many short excurrent somewhat branched tubules. This structure can be paralleled in the bones of the alligator and other reptiles, and is not always easy to be distinguished from the corresponding

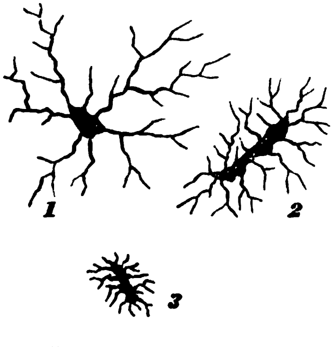

Diagram LXXV. Scale magnified 200 times.

1. Lacunæ in bony scale of lepidotus. 2. Lacunæ in leg bone of alligator.
3. Lacunæ in phalangal bone of Rhamphorhynchus Bucklandi.

formations in a bird—e.g. emu, heron, dinornis. What appear to be pneumatic foramina are observed in some of these bones. The long internal cavities are such as seem destined to admit air within the extremely thin close-textured cylinder of bone; and in one case of a scapula near the articulation we see thin plates of bone crossing the cavity, and contributing to strengthen it where resistance was needed.

Of dorsal vertebræ we have no trace; of ribs a few specimens shewing furcate head and considerable length of slender, almost straight shaft. Greatest length observed, 2·25 inches, the specimen belonging to the anterior dorsal series. The distance over both articulating faces is 0·4 inch; the shaft is only 0·125 in diameter; it was hollow.

Coming to the pelvic region, we must regret the absence of sacrum, ilium, pubis, and ischium. There seems to be no complete femur in our collection, except the small bent bone, Diagram LXXVI. fig. 1. The beautiful slender straight bone represented in Diagram LXXVI. fig. 2, according to my latest examination and comparison with dimorphodon [1] seems to be a tibia.

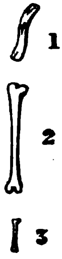

Diagram LXXVI. Rhamphorhynchus Bucklandi. Scale one-fifth of nature.
1. Femur. 2. Tibia. 3. Phalangal bone.

This bone, remarkable for its regularly cylindrical aspect, except where it expands toward the extremities, is hollow throughout; the external sheath being somewhat thickened in its substance in the middle parts of the shank. Length 3·6 inches; least diameter 0·15. The extremities are too much engaged in the stone to allow of satisfactory description. Accepting this for tibia, we may assume the femur to have been 2·4 inches long.

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[1] Fossil Reptilia of the Lias, Pal. Soc. Memoirs for 1869.

Finally, we have one phalangal bone represented (fig. 3) below the tibia; but whether it belongs to the leg, or a small finger of the wing, is not easy to determine; at present I refer it to the leg.

We have no vertebræ of the tail.

Such are the elements to be employed for reconstructing, at least in imagination, a creature which, more than realizing the harpy of fable, was once a member of a not inconsiderable race of predaceous tyrants of the air while as yet ordinary birds were of rare occurrence. The whole group appears to be mesozoic; contemporaries of the ichthyosaurus, plesiosaurus, and pleiosaurus, and standing in much the same relation to them as the gulls and terns and pelecanidæ of to-day to our living dolphins and other more bulky carnivorous cetacea. Gifted with ample means of flight, able at least to perch on rocks and scuffle along the shore, perhaps competent to dive, though not so well as a palmiped bird, many fishes must have yielded to the cruel beak and sharp teeth of the rhamphorhynchus[k].

If we ask to which of the many families of birds the analogy of structure and probable way of life would lead us to assimilate rhamphorhynchus, the answer must point to the swimming races with long wings, clawed feet, hooked beak, and habits of violence and voracity; and for preference, the shortness of the legs, and other circumstances, may be held to claim for the Stonesfield fossil a more than fanciful similitude to the groups of the cormorants and other marine divers, which constitute an effective part of the picturesque army of robbers of the sea.

Marked, then, by several important characters which conduct away from ordinary reptiles, why are not the pterodactylian creatures ranked with birds toward which they seem to stretch their wings? If we strive to insulate the modern beautiful tenants of the air from the strangely-shaped beings which preceded most of them in the order of time, and say birds are essentially and even exceptionally warm-blooded, how are we to be assured that the interior temperature of rhamphorhynchus was simply regulated by that of the atmosphere? A particular double and complete blood circulation goes with high temperature, and a special system of

[k] 'Tristius haud illis monstrum, nec sævior ulla
Pestis et ira Deûm Stygiis sese extulit undis.'
ÆN. iii. 214, 15.

aeration and respiration; but among reptiles there are various degrees of incompleteness in these respects; and the bones of pterodactyles were hollow, perhaps pneumatic like those of birds[l]. Feathers, we may truly say, accompany this high temperature in birds, and seem to be essential, certainly auxiliary to it; and no signs of feathers have been noticed among any of the pterosaurians, while they have been seen in another fossil (archæopteryx), of somewhat dubious nature, found in strata of the oolitic period. The occurrence of a feather then would, according to this way of reasoning, turn the balance and constitute a bird.

Turning now to points of structure likely to be permanently preserved, we may observe that birds as a rule have no true teeth, and specially no such fangs as those which make the mandible of rhamphorhynchus so formidable. Again, the wings of birds are supported on the inner fingers of the hand[m], those of the fossil animals on the outer finger only. Moreover, the feet of birds which have four digits differ from those of rhamphorhynchus, also having four, by a curious law which seems to apply to birds and reptiles generally. It consists in this: the number of joints in the toes increases in both cases from the inner toe outwards, but not in the same way. Thus in a bird with four toes the numbers run 2, 3, 4, 5, but in a crocodile 2, 3, 4, 4: so is it in rhamphorhynchus.

Again, birds almost without exception have their sternal girdle completed by a furcula, and none such has yet been recognized in the pterosaurians. Also there is a considerable difference in the form of the sternum, though in both some degree of carination occurs. Lastly, in the tail of a bird the vertebræ are gathered up into a short compact group, but in the rhamphorhynchi they run out to an extreme length. So indeed they do in archæopteryx, which is voted to have been a bird, though not well fitted for flight; but had not the fine slaty stone of Solenhofen preserved traces of so delicate an object as a soft feather, that admirable fossil must have taken its place among the lower, though not less interesting, nor probably less active, natural agents whose reptilian affinity and ornithic analogy seem to be sufficiently indicated by these brief remarks[n].

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[l] I have not satisfied myself that pneumatic foramina can be traced in the long bones of Stonesfield.

[m] On questions of this order in Comparative Anatomy I have the privilege of unreserved communication with my colleague Dr. Rolleston.

FOSSIL BIRDS.

When first the long hollow bones of the pterodactyles of Stonesfield attracted attention, they were naturally referred to birds; since they have been more carefully studied, it is rare to meet with notices of any bones found at Stonesfield which were supposed to possess avian characters. The Rev. J. B. P. Dennis published some remarks on the 'Existence of Remains of Birds' in this deposit, founded on a specimen in the possession of W. Adams, Esq., of Buriton, near Petersfield[o]. This bone, when examined microscopically, presented rather close resemblance to the structure of the humerus of a heron, specially in the lacunæ and small canaliculi leading from them.

In the absence of evidence, palæontologists of cautious habits of thought will not venture to affirm or deny the existence of birds at the epoch of time or in the region of the earth for which the lagoon of Stonesfield became a rich museum. They will not affirm it, either on the ground of the proved analogy of the rhamphorhynchus with the bird, leading to the expectation that the groups were contemporaneous; nor on the ground of a necessary succession in the several classes of animals, rising always upwards, so that as mammalia have been certainly found at Stonesfield in the oolite, and in some other localities in the rhætic beds, birds must have come into being; still less will he risk the existence of birds on the vague dream that all the known classes of animals co-existed through all mesozoic if not all ancient time, though some have left no remains to confirm their claim of a long family history. Yet he will not hastily deny that birds may have been flying over the water or perching among the trees in the period when so great a number of plants and insects occupied the land, and so great a variety of oceanic life prevailed. Rare, it is probable, at the present day would be the reliquiæ of birds in the sea; perhaps we might be justified rather in looking for them in lacustrine deposits than in marine strata; perhaps rather among insectivorous birds, as companions of the little mammalia next to be noticed, than among waders, swimmers, and divers, whose functions seem to have been well supplied by the volant lizards already catalogued. Be it as it may, there is no sure evidence yet collected to prove the presence of birds of any order at Stonesfield.

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[n] Consult for extended discussions on the question of the ornithic affinity of pterodactylians generally, Cuvier, Ossemens fossiles, v. plate 11; Professor Owen, in Pal. Soc. Mem. for 1857; and Mr. Seeley on Ornithosauria, 1870.

[o] Microscopical Journal, 1857, p. 63.

FOSSIL MAMMALIA.

The specimens now to be noted, though amongst the smallest of fossils, have had a greater influence on the course of geological opinion than even the huge reptiles their contemporaries; for they were the first discovered proofs of the existence of warm-blooded quadrupeds in the midst of the oolitic ages. Other discoveries since made have indeed established this kind of life as far back as the later triassic period, and produced fresh evidence of the same kind in the lacustrine strata of Purbeck. But still these Stonesfield mammals, resembling some of Australia, and associated with fishes, shells, and plants, of forms which can be almost exactly matched by the living productions of that exceptional region, stand up amidst the obscurity of past ages, northern prototypes of a singular system of modern life belonging to a distant quarter of the globe.

Taken in the order of discovery, the first to be noticed is a specimen of Amphitherium Broderipii, which was obtained with other fossils from Mr. Joshua Platt (well known as an able collector) about the year 1764, by Sir Christopher Sykes, during his residence in Oxford. This specimen I found in the cabinet of his descendant, the Rev. C. Sykes, of Rooss, in Holderness, in 1828; and at my request he generously presented it to the Museum of the Yorkshire Philosophical Society (Diagram LXXX.).

At some time before 1818, Mr. Broderip, a student of Corpus Christi College, obtained two specimens, one of which, now known as Amphitherium Prevostii, he allowed his friend Mr. Buckland to possess. Mr. Broderip's specimen, named Phascolotherium Bucklandi, was transferred to the British Museum; Dr. Buckland's remained at Oxford, and was there inspected by Cuvier during a short visit to England in 1818[p].

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[p] Youngest of a large entourage at Sir J. Banks' conversazione, I had then the privilege of listening to this the greatest of modern biologists.

AMPHITHERIUM PREVOSTII.

Speaking of the fossil remains of Stonesfield, the author of the 'Ossemens Fossiles' observes[q]:—'Parmi ces innombrables fossiles marins sont toutefois quelques os longs qui ont paru venir d'oiseaux de l'ordre des échassiers, et même, à ce qu'on assure, deux fragmens de machoire qui, lors d'une inspection rapide que j'eu pris à Oxford en 1818, me semblèrent de quelque didelphe.' And in a note on this passage:—

'M. Prévost, naturaliste bien connu, qui voyage dans ce moment en Angleterre, vient de m'envoyer le dessin d'une de ces machoires; il me confirme dans l'idée que la première inspection m'en avoit donnée. C'est celle d'un petit carnassier dont les machelières ressemblent beaucoup à celles des sarigues; mais il y'a dix de ces dents en série, nombre que ne montre aucun carnassier connu. Dans tous les cas, si cet animal est vraiment du schiste de Stonesfield, c'est une exception notable à la règle, d'ailleurs si générale, que les couches de cette ancienneté ne recelent point les restes de mammifères.'

This passage may be taken as an index of the state of geological opinion of the time, as well as an example of the masterly intellect and superior knowledge by which so many errors and prejudices were swept away.

Buckland, adopting the opinion of Cuvier, declared positively the mammalian nature of the Stonesfield jaws, and this decision appeared for a while to satisfy geologists that the 'rule' to which Cuvier referred was at least liable to exception[r]. As time rolled on, other specimens appeared and were examined by Broderip, who added his valuable authority to the opinion of his friend. But this additional information was followed by a revival of the old scepticism in a new form. M. Prevost admitted the mammalian character of the jaws, but denied the antiquity of the deposit[s]. To this objection Dr. Fitton's 'Memoir on the Stonesfield Strata[t]' was a complete and satisfactory answer.

A new ground of objection was then taken, and comparative anatomy, excited by De Blainville, rose against its master, and declared Cuvier to be wrong, and the jaws to be not mammalian, but reptilian, or even ichthyan[u].

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[q] Vol. v. p. 349. Second Edition, 1825. The long bones belonged to rhamphorhynchus.

[r] Geol. Trans., 1823. Second Series, vol. i. p. 399.

[s] Ann. des Sci., iv. 396. (1825).

[t] Zool. Journal, 1828.

Even Agassiz admitted these objections to some extent, and wished at least to reduce the mammalian rank of the creatures from truly land animals to littoral seals or marine cetacea[x]. And Grant employed elaborate arguments in favour of their reptilian origin[y].

Valenciennes[z] replied to the opposition of Blainville, who quickly rejoined with new doubts[a], and a final preference for the opinion that the jaws were those of saurians, or even fishes.

It must not be thought that this diversity of opinion among competent anatomists implies want of candour, or want of research. In fact, the problem was and is a singularly difficult one. For they had to decide on the affinities of the animal from a knowledge of only one element of its structure—*the lower jaw with its teeth.* Can we, it may fairly be asked, from a lower jaw with teeth, unsupported by any other part of the bony fabric, infer with sufficient probability the class, order, and family of animals to which a specimen belongs? The answer is affirmative: the process is by marked steps, some of which may be here stated, the full arguments having been clearly given by Owen in his admirable work entitled 'British Fossil Mammals.'

It must be one of the vertebrata.

It cannot be one of the class of fishes, because of the teeth which are of three orders, molars, premolars, and incisors, and because of the double fangs of the molars deeply implanted in bony sockets.

The same circumstances are decisive against a reference of the jaw to birds, chelonians, serpents, and batrachians.

In existing nature we have therefore only to look into the saurian reptiles, or some order of mammalia, and to consider these classes in regard to dentition and the structure of the lower jaw-bone.

The teeth of living reptiles are extremely variable, but they never exhibit, as in these fossils, true and false molars with different crowns.

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[u] Doutes sur le pretendu Didelphe Fossile de Stonesfield. Comptes rendus, 1838, August 20.

[x] German Translation of Buckland's Bridgwater Treatise.

[y] Thomson's British Annual, 1839.

[z] Comptes rendus, 1838, September.

[a] Comptes rendus, 1838, October 6.

The lower jaws of reptiles generally are composite; and Dr. Grant regarded the Stonesfield jaw in the same light, in consequence of a small groove at the base, which he supposed to separate the dentary and opercular pieces; but there is really 'no deep dividing fissure between dentary and opercular,' but a distinct smooth groove, as in myrmecobius and wombat, the mark of a blood-vessel.

It is needless to pursue this argument; the result in favour of the mammalian nature of the jaw is now universally accepted. Three genera have been recognized at Stonesfield, and have received the names of Amphitherium, Phascolotherium, and Stereognathus.

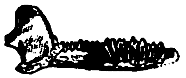

Diagram LXXVII. Amphitherium Prevostii. Oxford Museum. Natural size.

Amphitherium Prevostii (Diagram LXXVII.). A small ferine animal, with a lower jaw filled with minute teeth, sixteen on each side; viz. six molar, six premolar, one canine, and three incisors. The molars have several cusps, three being principal; the premolars have one principal cusp. Each has a double fang, rather deeply rooted in the compressed jaw. The diagram referred to represents the specimen which was obtained by Buckland, and submitted to the examination of Cuvier in 1818. It is the left ramus, seen internally. The fangs of the anterior molars are exposed; the crowns of all. The coronoid process rises boldly in a broad thin expansion, having below it a strong convex, prominent, articular condyle, and an equally conspicuous and angular element. There is a little horizontal groove below the last molars—mark of a blood-vessel.

Diagram LXXVIII. represents a second specimen placed by

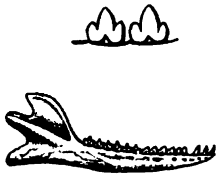

Diagram LXXVIII. Amphitherium Prevostii. Oxford Museum. Natural size.

Dr. Buckland in the Oxford Museum, which is referred to the same species as that first discovered. It shews the exterior face. There are traces of all the teeth, except the canine, whose place is marked by an interval. The teeth are not in general perfect, having been somewhat chipped; but the number can be well determined. There is some difference between this specimen and that previously noticed, in the form of the jaw, which seems in this to be not so deep, in the position of the articular face in relation to the line of the jaw, and in the degree of prominence of the angular termination [b].

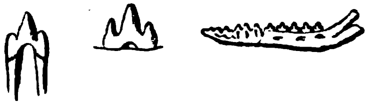

Diagram LXXIX. Amphitherium Prevostii. Oxford Museum. Natural size.

A third specimen, represented above, lately received from Stonesfield, adds to the information regarding the teeth, though it be quite incomplete as to the figure of the jaw. The teeth are unusually perfect, and well cleared from the stone. They have not the crowded aspect in Diagram LXXVIII. They are smooth, and are such as to imply vermivorous and insectivorous habits. In all the specimens which shew the angular termination of the jaw, that part has a little bend inward, a character observed in several living marsupialia; the number of molar teeth is so great as to surpass that of any known ferine quadruped; but there is an approach to this circumstance in myrmecobius, a small Australian marsupial. To this, on the whole, the fossil is probably most closely allied; but certainly the small marsupalia generally seem to be the nearest kinsfolk.

Amphitherium Broderipii is the name given to the second species

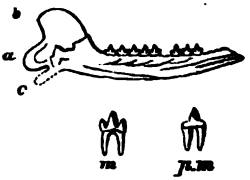

Diagram LXXX. Amphitherium Broderipii. Yorkshire Museum. Natural size.

of the genus, which is illustrated by the specimen in the Yorkshire

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[b] This specimen has been figured by Owen, in British Fossil Mammalia, p. 29; Lyell, Manual, chap. xx.

Museum. It is the left branch of the lower jaw, seen internally. It shews sockets for the incisor and canine teeth with one fang; sockets for three premolars with two fangs; three premolars in place; a vacancy for the first true molar, and then five molars *in situ*. These molars shew three principal and three accessory cusps, these latter being on the inner side. The teeth are smooth and uninjured; all the molars tricuspid and placed with great regularity. The posterior part of the jaw seems to differ from the same part in A. Prevostii, by the nearer approximation of the condyle and angular processes [c].

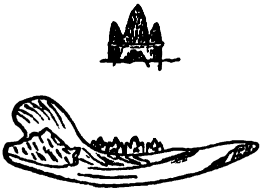

Diagram LXXXI. Phascolotherium Bucklandi. Oxford Museum. Natural size. The upper figure enlarged to shew the undulated surface.

Phascolotherium Bucklandii, the species which fell to Mr. Broderip, on the memorable occasion when first the two friends divided the spolia opima of Stonesfield, is considerably different in form and essential points from those already mentioned. The accomplished naturalist, whose loss we even yet deplore, generously presented his treasure to the British Museum, after having published observations of remarkable interest, and assigned it a place among the didelphidæ [d]. The drawing above given is taken from a specimen in the Oxford Museum, seen internally, less complete in respect of the teeth, but otherwise not less instructive than the original typical example. These jaws are larger than either of those noticed already; the lower border is more uniformly arched; the coronoid process slopes more on its anterior edge; neither of the specimens shews clearly the angular process, which was apparently bent more suddenly inward than in the other fossils. The teeth are counted by Broderip as seven molars and premolars, one canine, three certain and probably a fourth incisor, making in all twelve teeth on each side. The molars are essentially tricuspid, with accessory smaller cusps on the inner edge; their surface I find to be minutely undulated with a sort of shagreen pattern, which does not appear in the teeth of the other genus.

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[c] Figures of this specimen have been given by Owen in the Geological Transactions, Second Series, vol. vi. Plate VI., and in British Fossil Mammals.

[d] On the Jaw of a Fossil Mammiferous Animal, found in the Stonesfield Slate. Zool. Journ., 1828, vol. iii., with a plate.

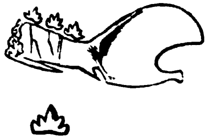

Diagram LXXXII. Interior aspect of lower jaw, referred to Phascolotherium Bucklandi, and magnified tooth to shew the quinquecuspid character more clearly than usual. The surface is distinctly 'chagrined,' with little approximate irregular pits. Natural size. Specimen in the collection of Mr. J. Parker.

Compared with the ordinary didelphys of Virginia, the correspondence is very obvious: similar teeth in the same number and general proportion. Still more close, in the opinion of Owen, is the alliance with thylacinus, a much larger marsupial of Australia; and thus we are conducted to the easy recognition of a second primæval genus of that now restricted family of quadrupeds.

STEREOGNATHUS.

Stereognathus ooliticus is the title of a fragment of lower jaw, which was made known by Mr. Charlesworth, as in the possession of the Rev. J. Dennis of Bury [e]. 'The specimen was part of the centre of one branch of the lower jaw; its curvature was very slight, and the concavity below. The section where it was broken across was rectangular, and as wide as deep. The surface presented no trace of suture or vascular lines. Three teeth remained, occupying half the length of the fragment, and one of these had six similar cusps arranged in two rows.'

The drawing of this little fossil (Diagram LXXXIII.), made by Mr. Bone, under the direction of Professor Huxley, represents three teeth in a fragment of the lower jaw, which is convex externally,

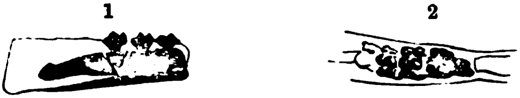

Diagram LXXXIII. Stereognathus ooliticus. Natural size.

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[e] Report of the Liverpool Meeting of the British Association, 1854.

of small depth, but relatively considerable breadth, whence the name of stiff or solid jaw. The most perfect of the teeth has six, nearly equal, curved cusps in two longitudinal rows, on a squarish crown; an arrangement not unlike what occurred in a tooth found in the Keüper of Diegerloch in Wurtemberg[f], and also not unlike the crowns of some pachydermata. The teeth have double fangs.

Professor Owen has fully described this curious specimen, and concludes it to have belonged to some quadruped much allied in dentition to pliolophus, and therefore to have been hoofed, with herbivorous habits of life—a very 'wee bit' of an artiodactylous mammal.

Until additional specimens occur, this jaw must remain without settled alliances. Some of the teeth classed as microlestes, found in rhætic beds, are multicuspid, and the cusps are in rows; there may have been other analogies.

The singular fact of only separate branches of lower jaws being found, and these to the extent of a dozen or more, belonging to four species, can only be explained by supposing the lower jaws to have been easily separable from the body, and to have become divided at the symphysis, through the feeble coherence there; and then the separated parts to have found rest from some watery transport at points removed from those where the main part of the body was deposited. This is a probable view. Every flood gives us occasion to see in English waters floating bodies of small decaying animals, whose open mouths are releasing the lower jaws, uncovered by integuments, while the rest of the skin-protected skeleton is carried far away.

Thus a picture of the ancient surface rises before us, in which the Stonesfield lagoon, full of fishes and mollusks, receives with every cyclonic storm drifted branches of cypresses and swarms of wind-wrecked insects, while the swollen land-streams bring down, but not with equal rate of motion, the bony remains of amphibious and terrestrial lizards, which perished on the banks and river beds, and the bodies of small mammals which had sported in the trees. Not far off were coral reefs, and great beds of shells, and fishes, and over all

> '. . . adsunt
> Harpyiæ, et magnis quatiunt clangoribus alas.'
> ÆN. iii. 225, 6.

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[f] A drawing of this tooth (named Microlestes by Dr. Oscar Franz) was lent me by the late lamented Dr. Falconer. The tooth is said to be lost.

FOSSILS OF THE GREAT OOLITE GROUP.

The following list of Great oolite fossils includes also those of the Bradford clay and Forest marble, which are in this district always close allies and often inseparable parts of the thicker oolitic series, but excludes those of the Stonesfield beds. Their partially estuarine character is chiefly manifested by drifted wood and bones of amphibious and terrestrial reptiles, and a few rare examples of a fresh-water bivalve. The localities are limited to the neighbourhood of Stonesfield and Oxford, for the purpose of presenting the forms of oolitic life in what seems one natural series, in a limited part of the sea-basin. The far richer assemblage which occurs at Minchin-Hampton has been made well known by the researches of Mr. Lycett. To his comprehensive work, in conjunction with Professor Morris, on the Great Oolite Fossils in the Memoirs of the Palæontographical Society, and to his Handbook for the Cotteswold Hills, recourse may be had for many excellent figures.

It is chiefly from the deep cutting on the railway near Northleigh, south of Stonesfield, and from other cuttings and quarries at Enslow Bridge and Islip, that we obtain our fossils from the oolite and the forest marble. Mr. Whiteaves was very successful in both localities. From his lists[g], the Memoirs of the Geological Survey, and our own explorations, the following Catalogue is prepared. The Islip fossils, marked F. M., are from white beds of clay, like that of Bradford, with partial beds of shelly stone, above the Great oolite. At Kirtlington Station and in the Enslow Bridge quarries the upper parts of the Great oolite, and in the cutting near Northleigh the middle and lower parts, have been examined.

So many of these fossils are repeated in the cornbrash, that sure upper limit of the Bath oolite series, that it seems natural and useful to combine in one catalogue all the species known in the immediate vicinity of Oxford, between the Stonesfield slate and the Oxford clay.

The following abbreviations are used :—G. O. for Great oolite; F. M. for Forest marble and Bradford clay; C. B. for Cornbrash.

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[g] Reports of the British Association, 1857.

PLANTS. Fragments of wood occur in all these strata.

ACTINOZOA.

- Anabacia orbulites. *Lam.* G. O. Kirtlington. F. M. Islip. C. B. Islip.
- Convexastræa Waltoni. *Edw.* G. O. Northleigh.
- Cyathophora Prattii. *Edw.* G. O. Northleigh. C. B. (O. G. S.)
- „ solida. n. s. *Phil.* G. O. Stonesfield.
- Isastræa explanata. *M'Coy.* G. O. Northleigh.
- „ limitata. *Lam.* G. O. Northleigh.
- Montlivaltia trochoides. *Edw.* G. O. Northleigh.
- Thamnastræa Lyellii. *Edw.* G. O. Northleigh, Enslow Bridge.

There is no true coral bed in these strata near Oxford.

ECHINODERMATA.

- Acrosalenia hemicidaroides. *Wr.* G. O. Northleigh, Kirtlington. C. B. Islip.
- „ Loweana. *Wr.* G. O. Cirencester. F. M. Islip.
- „ pustulata. *Forbes.* F. M. Islip.
- „ spinosa. *Ag.* F. M. Islip. C. B. Islip.
- Clypeus Mulleri. G. O. Kirtlington.
- „ Plotii. G. O. Northleigh, Enslow Bridge, Kirtlington. C. B. Islip.
- Echinobrissus clunicularis. *Lhwyd.* C. B. Islip.
- „ Griesbachii. *Wr.* G. O. Northleigh.
- „ orbicularis. C. B. Islip.
- „ Woodwardii. *Wr.* G. O. Northleigh.
- Hemicidaris Bradfordiensis. *Wr.* F. M. Islip. C. B. Islip.
- Holectypus depressus. F. M. Islip. C. B. Islip.
- Pedina Smithii. *Wr.* C. B. Islip.
- Pseudodiadema Bailyi. *Wr.* C. B. Islip.
- „ Parkinsoni. F. M. Islip. C. B. Islip.
- Pygurus Michelinii. C. B. Islip, Kirtlington.
- Stomechinus intermedius. *Wr.* C. B. Islip.

In this list no star-fishes are mentioned; pentacrinite joints occur rarely.

ANNELLIDA.

- Serpula, large species. F. M. Islip.
- „ undetermined. G. O., F. M., and C. B. at various localities.

CRUSTACEA.

- Glyphea rostrata. *Phil.* G. O. Kirtlington. C. B. Kidlington.

POLYZOA.

- Alecto dichotoma. C. B. Islip.
- Cricopora straminea. *Phil.* F. M. Islip. C. B. Islip.
- Diastopora diluviana. *Edw.* G. O. Kirtlington. C. B. Islip.
- Terebellaria ramosissima. *Lam.* F. M. Islip.

This very small series, as compared with that near Bath, is represented by very few specimens, except in the case of diastopora.

BRACHIOPODA.

Rhynchonella concinna. *Sow.* G. O. Kirtlington. F. M. Islip. C. B. Islip.
„ Morieri. *Dav.* C. B. Islip.
„ obsoleta. *Sow.* G. O. Northleigh Cutting.
Terebratula cardium. *Lam.* F. M. Islip. C. B. Islip.
„ digona. *Sow.* G. O. Kirtlington. F. M. Islip.
„ globata. *Sow.* G. O. Northleigh Cutting.
„ hemisphærica. *Sow.* C. B. Islip.
„ intermedia. *Sow.* C. B. Islip, Kidlington, Bladon.
„ maxillata. *Sow.* G. O. Northleigh, Kirtlington. F. M. Islip.
„ obovata. *Sow.* C. B. Islip, Kidlington, Bicester.

Terebratula maxillata is the most prevalent form in the Great oolite, T. obovata in the cornbrash. Rhynchonella concinna goes through the whole group.

MONOMYARIA.

Avicula echinata. *Sow.* C. B. Islip, Kirtlington, Kidlington, Bicester.
Gervillia acuta. *Sow.* G. O. Northleigh Cutting, Kirtlington. F. M. Islip. C. B. Islip.
„ crassicosta. *M.* and *L.* G. O. Kirtlington.
„ Islipensis. *Lyc.* G. O. Northleigh. C. B. Islip.
„ monotis. *Desl.* G. O. Kirtlington.
„ ovata. *Sow.* G. O. Kirtlington. C. B. Islip.
Lima cardiiformis. *Sow.* G. O. Northleigh. F. M. Islip. C. B. Islip.
„ duplicata. *Sow.* G. O. Northleigh, Kirtlington. F. M. Islip. C. B. Islip.
„ gibbosa. *Sow.* C. B. Islip.
„ impressa. *M.* and *L.* F. M. Islip. C. B. Islip.
Ostrea acuminata. *Sow.* G. O. Northleigh Cutting. C. B. Islip.
„ gregarea. *Sow.* G. O. Northleigh, Kirtlington.
„ Sowerbii. G. O. Northleigh, Kirtlington.
„ subrugulosa. G. O. Northleigh, Kirtlington.
Pecten annulatus. *Sow.* G. O. Kirtlington. F. M. Islip. C. B. Islip.
„ arcuatus. *Sow.* G. O. Kirtlington. F. M. Islip. C. B. Islip.
„ divaricatus. n. s. F. M. Islip.
„ fibrosus. *Sow.* G. O. Northleigh.
„ hemicostatus. *M.* and *L.* C. B. Islip, Kidlington.
„ lens. *Sow.* G. O. Northleigh. F. M. Islip. C. B. Islip.
„ personatus. *Goldf.* F. M. Islip. C. B. Islip.
„ rigidus. *Sow.* F. M. Islip. C. B. Kidlington.
„ vagans. *Sow.* G. O. Northleigh. C. B. Islip.
Perna rugosa. *M.* and *L.* G. O. Northleigh.
Placunopsis socialis. G. O. Northleigh, Kirtlington. F. M. Islip. C. B. Islip.
Pteroperna costatula. *M.* and *L.* G. O. Kirtlington.
„ emarginata. G. O. Kirtlington. F. M. Islip.

In this list a general reduction of the number of species may be remarked as compared to the inferior oolite, with an agreement in genera. Avicula echinata, abundant in and characteristic of cornbrash generally, is perhaps confined to that rock in this district.

DIMYARIA.

Arca æmula. *Phil.* G. O. Northleigh. C. B. Islip.
„ minuta. *Sow.* F. M. Islip.
„ Prattii. *M.* and *L.* G. O. Kirtlington.
„ rugosa. *M.* and *L.* C. B. Islip.
Astarte angulata. *M.* and *L.* G. O. Northleigh, Kirtlington.
„ extensa. *Phil.* G. O. Kirtlington.
„ interlineata. *Lye.* F. M. Islip.
„ minima. *Phil.* F. M. Islip.
„ rustica. *Lyc.* F. M. Kirtlington. C. B. Islip.
„ squamula. *D'Arch.* G. O. Kirtlington.
„ Wiltoni. *M.* and *L.* G. O. Kirtlington.
Cardium Buckmanni. *M.* and *L.* G. O. Northleigh. C. B. Islip.
,, incertum. *Phil.* G. O. Kirtlington.
,, lingulatum. *Lyc.* G. O. Kirtlington.
,, Stricklandi. *M.* and *L.* G. O. Northleigh, Kirtlington. F. M. Islip. C. B. Islip.
,, subtrigonum. *M.* and *L.* G. O. Kirtlington. C. B. Islip.
Ceromya Bajociana. *D'Orb.* G. O. Enslow Bridge.
Corbis elliptica. *Whit.* F. M. Kirtlington.
Corbula attenuata. *Lyc.* G. O. Kirtlington.
,, Hulliana. *Mor.* F. M. Kirtlington.
,, involuta. *Goldf.* F. M. Islip. C. B. Islip.
,, Islipensis. *Lyc.* G. O. Kirtlington. C. B. Islip.
,, MacNeillii. *Mor.* F. M. Islip. C. B. Islip.
Cypricardia Bathonica. *D'Orb.* G. O. Northleigh. C. B. Islip.
„ nuculiformis. *Röm.* G. O. Northleigh.
„ rostrata. *Sow.* G. O. Northleigh, Kirtlington. F. M. Islip. C. B. Islip.
Cyprina depressiuscula. *M.* and *L.* G. O. Kirtlington.
,, Islipensis. *Lyc.* G. O. Kirtlington. C. B. Islip.
„ Loweana. *M.* and *L.* G. O. Northleigh, Kirtlington. F. M. Islip. C. B. Islip.
Gresslya peregrina. *Phil.* C. B. Islip.
Homomya gibbosa. *Sow.* C. B. Kirtlington.
Isocardia minima. *Goldf.* C. B. Islip.
Leda lachryma. *Sow.* F. M. Islip. C. B. Islip.
,, mucronata. *Sow.* C. B. Islip.
Limopsis ooliticus. *D'Arch.* G. O. Kirtlington. F. M. Islip.
Lithodomus inclusus. *Phil.* C. B. Islip.
Lucina Bellona. *D'Orb.* G. O. Northleigh.
,, cardioides. *D'Arch.* G. O. Kirtlington.
,, striatula. *Buv.* G. O. Kirtlington.
Macrodon Hirsonensis. *D'Arch.* G. O. Northleigh. C. B. Islip.
Modiola aspera. *Sow.* C. B. Islip.
„ compressa. *Portl.* C. B. Islip.

Modiola cuneata. *Sow.* G. O. Northleigh.
„ imbricata. *Sow.* G. O. Northleigh, Kirtlington. F. M. Islip. C. B. Islip.
„ Sowerbiana. *Bronn.* C. B. Islip.
Myacites Beanii. *M.* and *L.* C. B. Kirtlington.
„ calceiformis. *Phil.* G. O. Kirtlington. C. B. Kirtlington.
„ dilatus. *Phil.* G. O. Northleigh.
„ decurtatus. *Phil.* G. O. Kirtlington. C. B. Islip, Kirtlington.
„ Scarburgensis. *Phil.* G. O. Kirtlington.
„ securiformis. *Phil.* C. B. Islip.
Mytilus sublævis. *Sow.* G. O. Northleigh. C. B. Islip.
Neæra Ibbetsoni. *M.* and *L.* G. O. Northleigh, Kirtlington. C. B. Islip.
Nucula Menkii. *Röm.* G. O. Kirtlington. C. B. Islip.
„ variabilis. *Sow.* G. O. Kirtlington. F. M. Islip. C. B. Islip.
Pholadomya acuticosta. *Sow.* F. M. Islip.
„ deltoidea. *Sow.* C. B. Islip, Kidlington, Bladon.
„ Heraulti. *Ag.* G. O. Northleigh, Kirtlington.
„ lyrata. *Sow.* C. B. Islip.
„ oblita. *M.* and *L.* G. O. Kirtlington.
„ ovulum. *Ag.* G. O. Northleigh.
„ solitaria. *M.* and *L.* G. O. Enslow Bridge.
Sowerbya triangularis. *Phil.* F. M. Islip.
Sphæra Madridi. *M.* and *L.* G. O. Kirtlington.
Tancredia axiniformis. *Phil.* G. O. Northleigh.
„ brevis. *M.* and *L.* F. M. Islip.
„ mactræoides. *Whit.* G. O. Northleigh.
„ similis. *Whit.* G. O. Kirtlington.
„ truncata. *M.* and *L.* F. M. Islip.
Trigonia costata. *Sow.* F. M. Islip. C. B. Islip.
„ Moretoni. *M.* and *L.* G. O. Northleigh. F. M. Islip. C. B. Islip.
Unicardium impressum. *M.* and *L.* G. O. Northleigh.

The generic accordance of this list with those of the Inferior oolite and Stonesfield beds, shews that where local interruptions of the truly marine beds do not prevail, the whole forms one natural group, specially fossiliferous near the base and near the top.

GASTEROPODA.

Actæonina bulimoides. *M.* and *L.* G. O. Kirtlington.
„ canaliculata. *Lyc.* G. O. Kirtlington.
„ Kirtlingtonensis. *Lyc.* G. O. Kirtlington.
„ Luidii. *Mor.* G. O. Kirtlington. F. M. Islip. C. B. Islip.
„ olivæformis. *Dunk.* G. O. Kirtlington.
„ parvula. *Röm.* G. O. Kirtlington.
„ scalaris. *Lyc.* G. O. Northleigh.
Alaria lævigata. G. O. Kirtlington.
„ trifida. G. O. Kirtlington.
Amberlya nodosa. *M.* and *L.* F. M. Islip.

Bulla . . . G. O. Kirtlington.
Ceritella acuta. *M.* and *L.* F. M. Islip.
„ longiscata. *Buv.* F. M. Islip.
„ rissoides. *Buv.* G. O. Kirtlington.
„ unilineata. *Sow.* G. O. Kirtlington.
Cerithium multiforme. G. O. Kirtlington.
„ quadricinctum. *Goldf.* F. M. Islip.
Chemnitzia variabilis. *M.* and *L.* C. B. Islip.
Crossostoma discoideum. *M.* and *L.* F. M. Islip.
Cylindrites acutus. *Sow.* F. M. Islip.
„ brevis. *M.* and *L.* G. O. Kirtlington.
„ excavatus. *M.* and *L.* C. B. Kidlington.
Emarginula scalaris. *Sow.* F. M. Islip.
Eulima communis. *M.* and *L.* G. O. Kirtlington. F. M. Islip.
Fibula eulimoides. *Whit.* G. O. Northleigh.
„ variata. *M.* and *L.* G. O. Kirtlington.
Monodonta Labdeyi. *M.* and *L.* G. O. Northleigh, Kirtlington.
„ Lycetti. *Whit.* F. M. Islip.
Natica Hulliana. *Lyc.* G. O. Kirtlington.
„ intermedia. *M.* and *L.* G. O. Kirtlington.
Nerinæa Dufrenoyi. *M.* and *L.* G. O. Northleigh.
„ Eudesii. *Desl.* G. O. Northleigh, Kirtlington.
„ funiculus. G. O. Kirtlington.
„ Voltzii. *Desl.* G. O. Northleigh, Kirtlington.
Nerita costulata. *Desl.* G. O. Northleigh.
„ hemisphærica. *Röm.* G. O. Northleigh.
„ involuta. *Lyc.* G. O. Kirtlington.
„ minuta. *Sow.* G. O. Kirtlington. F. M. Islip.
„ rugosa. *M.* and *L.* G. O. Northleigh.
Patella cingulata. *Goldf.* G. O. Kirtlington. F. M. Islip. C. B. Islip.
Phasianella elegans. *M.* and *L.* G. O. Kirtlington.
„ Leymerici. *D'Arch.* G. O. Kirtlington.
Rissoina acuta. *Sow.* G. O. Kirtlington.
„ duplicata. *Sow.* F. M. Islip.
„ lævis. *Sow.* F. M. Islip.
Stomatia Buvignieri. *M.* and *L.* G. O. Northleigh.
Trochus Ibbetsoni. *M.* and *L.* G. O. Northleigh, Kirtlington. F. M. Islip.
„ spiratus. *D'Arch.* G. O. Kirtlington. F. M. Islip.

Results similar to those mentioned for the bivalve mollusks may be accepted for the gasteropods.

CEPHALOPODA.

Ammonites discus. *Sow.* C. B. Kirtlington.
„ subcontractus. *Sow.* G. O. Kirtlington.
„ sp. resembling A. subradiatus. *Sow.* C. B. Islip.
Nautilus Baberi? F. M. Islip.

The reduction of cephalopoda generally, and the absence of belemnites, are remarkable.

FISHES. Teeth of Hybodus, Pycnodus, and Strophodus, and scales of Lepidotus, occur in the Great oolite of Kirtlington Station and Enslow Bridge.

REPTILIA.

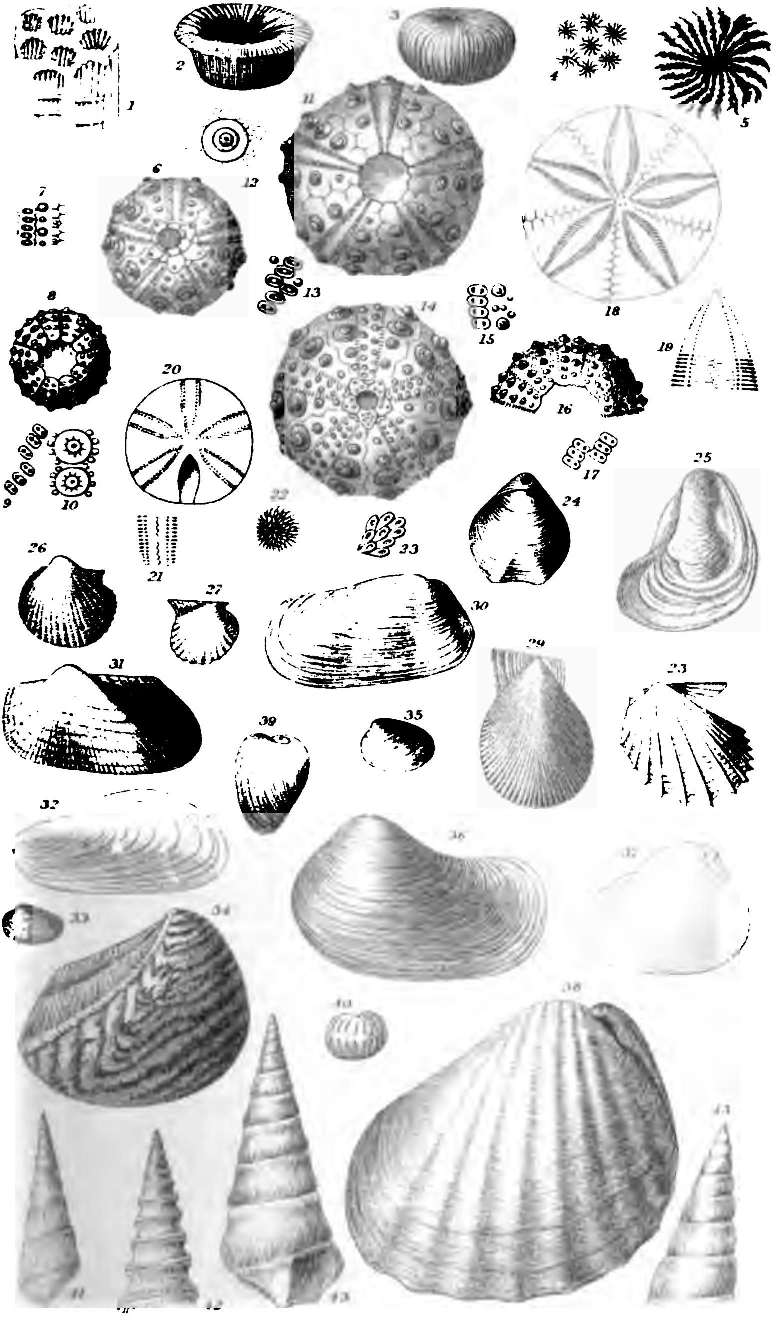
Ceteosaurus Oxoniensis and C. Glymptonensis. G. O. Kirtlington Station Quarries, Glympton, Chapelhouse, and other quarries near Chipping-Norton, Buckingham, &c.
Megalosaurus Bucklandi. G. O. Kirtlington Station, Enslow Bridge.
Teleosaurus brevidens. *Phil.* G. O. Enslow Bridge, Kirtlington Station.
„ subulidens. *Phil.* G. O. Enslow Bridge, Kirtlington Station Quarries. C. B. Kidlington.

REFERENCE TO PLATE XI., CONTAINING FOSSILS OF THE GREAT OOLITE, FOREST MARBLE, AND CORNBRASH.

1. Cyathophora solida. n. s.
2. Montlivaltia Smithii.
3. Anabacia orbulites.
4. Thamnastræa Lyelli. Cells.
5. Magnified view of one cell.
6. Acrosalenia Loweana.
7. Half of an ambulacral row.
8. Pseudodiadema Bailyi. *Wr.*
9. The bitriporous ray.
10. Tubercles magnified and radiated.
11. Pedina Smithii.
12. Tubercle not radiated, surrounded with small granules.
13. The bitriporous ray.
14. *Hemicidaris Stokesii.
15. A biporous ray with parallel granules. The tubercles are radiated.
16 *Pseudodiadema depressum.
17. Bitriporous ray. The tubercles are radiated.
18. Pygurus Michelinii.
19. The ambulacral structure.
20. Echinobrissus orbicularis.
21. The ambulacral structure.
22. Diastopora diluviana. n. s.
23. „ magnified.
24. Terebratula obovata.
25. Ostrea Sowerbii.
26. Avicula echinata. Left valve.
27. „ Right valve.
28 „ costata. Left valve.
29. Pecten divaricatus. n. s.
30. Myacites Beanii.
31. Arca rugosa.
32. Modiola imbricata.
33. Corbula involuta.
34. Trigonia Moretoni.
35. Nucula Waltoni.
36. Homomya gibbosa.
37. Cyprina Islipensis.
38. Pholadomya deltoidea.
39. Actæonina Kirtlingtonensis.
40. Nerita minuta.
41. Nerinæa Dufrenoyi.
42. „ Eudesii.
43. Fibula eulimoides.
44. „ variata.

* These echinodermata are probably not confined to Stonesfield beds.

GREAT OOLITE, FOREST MARBLE, *and* CORNBRASH.



Drawn by J P

Engraved by J W L

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OXFORD

CETEOSAURUS.

The earliest notice of this mighty lizard is that communicated to the Geological Society of London, on the 3rd of June, 1825, by John Kingdon, Esq., who related the discovery of vertebræ and other bones in the oolite of Chapelhouse, near Chipping-Norton. The bones were said by Mr. Kingdon to have been taken from the quarries of the lower oolite. Chapelhouse stands on the upper or Great oolite of Bath, but near it the lower or Inferior oolite makes an inconspicuous appearance. From an examination of the quarries and of the specimens, and inquiries in the neighbourhood, it appears to me that they lay in the upper of these rocks, according to the distinction now adopted by the National Survey.

These bones, or a portion of the 'find,' came to the hands of Dr. Buckland, probably not many years after the date of Mr. Kingdon's notice, and they are now in the University Museum.

Dr. Buckland's attention being drawn to the subject while composing the Bridgwater Treatise, he acquired specimens from Thame and Enstone, which appeared to be congeneric, and received a valuable contribution from his friend William Stowe, Esq., who, residing at Buckingham, was well informed of the objects of geological interest which occurred in the quarries and clay pits of the neighbourhood. The following letter from Dr. Buckland to Mr. Stowe will shew how sagaciously the first traces of a remarkable discovery were interpreted and followed up by my great predecessor in office :—

'OXFORD, *December* 4, 1834.

'My dear Sir,—I am much obliged by your kindness in forwarding to me the basket of bones, which I received yesterday. They are all of saurian origin; that which has been rubbed down is probably a vertebra of a large crocodile; and the largest of all a caudal vertebra of some yet undescribed reptile of enormous stature, larger than the iguanodon, and of which I am collecting scattered fragments into our Museum, in hope ere long of being able to make out its history.

'Four large dorsal vertebræ of this animal were some time since presented to our public collection by a gentleman of Thame; more recently another, apparently a lumbar vertebra, has been added from

Enstone; and I am not without hopes that your friend, to whom the bone found at Buckingham belongs, will be disposed to aid in my contemplated discovery of the real nature of this unknown animal, by adding his name also to the list of our benefactors, and increasing twenty-fold the value of his specimen to the scientific world, by placing it in company which it will itself illustrate, and by which it will be illustrated. Five boxes, full of nearly as large bones of another reptile from the Isle of Wight, were presented to our Museum by a gentleman who found them on his estate at Yaverland last summer; and I need not tell you that the collection of fossil bones in the Oxford Museum is one of the finest in the world.

WM. BUCKLAND.'

Professor Owen, writing of these bones in 1841, informs us that 'a few large caudal vertebræ, and other bones of the ceteosaurus, have been discovered in the oolite of the neighbourhood of the town of Buckingham,' and form part of Dr. Buckland's Museum [h].

No vertebræ corresponding to these remarks can now be identified in the Oxford Museum. The form of the large caudal vertebra noticed in Dr. Buckland's letter is however preserved to science by an admirable cast, which was sent by him to the donor, and is now, by the gift of his son, Mr. Alfred Stowe, M.A., of Wadham College, placed in the Bucklandian collection.

The next occurrence was noted in Northamptonshire.

About the year 1840, in cutting the railway from London to Birmingham, a considerable number of gigantic bones occurred at Blisworth, within an area of twelve feet by eight feet. Besides five vertebræ agreeing with those already mentioned, bones supposed to be of the fore-limbs and sternal arch, and a portion of rib, were recognized by Professor Owen, who received the specimens from Miss Baker [i]. They were from the Great oolite. Their present 'whereabout' has not been ascertained.

About the same time, other specimens were discovered which are noticed by Professor Owen in the Report already referred to, in the following terms:—'In the Museum of Professor Sedgwick there is a caudal vertebra of the ceteosaurus, from the neighbourhood of Stratford-on-Avon,' (probably Stony-Stratford is meant). Staple-

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[h] Reports of British Association for 1841, p. 101.

[i] Geol. Soc. Proc. 1841, June 30; vol. iii. p. 460.

Hill, near Wotton, three miles north-west of Woodstock, is another locality for remains of ceteosaurus, quoted by Owen; and to this I may add the neighbouring village of Glympton, from whence vertebræ were sent by Mr. Barnett to the Oxford Museum.

We may safely conclude that all the places indicated (excluding Thame) belong to the area of the Great oolite rocks, the same, in fact, as those which have yielded the greater series next to be noticed.

We now come to the locality which has proved the richest of all yet examined for bones of ceteosaurus—the quarries at Gibraltar, near Enslow Bridge, and close to the railway station for Kirtlington and Bletchingdon, eight miles north of Oxford. The quarries at this place have been wrought for common building and road-making and lime-burning from ancient time; and a considerable number of bones of teleosaurus, a few of megalosaurus, and plenty of teeth of other reptiles and of fishes have been obtained by the workmen. But there is no record of any very large bones being disinterred till the railway-cutting was made there, which gave so much information of the succession of strata immediately below the cornbrash (p. 154). It was then that the attention of Mr. Hugh E. Strickland, M.A., of Merton College, was drawn to the locality, and was rewarded by a great discovery.

The workmen took up the thigh-bone of an unknown lizard, fifty-one inches long, entire in the ground, but compressed and shattered, so that a hundred fragments required careful readjustment. This being accomplished, the whole well cemented, and bound round with wire, the bone resumed its original aspect, and was long the object of admiration in the Oxford class-room for geology[k]. Here it was examined by Mantell and Owen, and by the latter was adopted as a species of ceteosaurus, and allied to the vertebræ which had about twenty years before been brought from near Chipping-Norton. A smaller bone which accompanied it has usually been regarded as a fibula, but in that case it must have belonged to an animal only half as large.

Twenty years later, in the beginning of 1868, the welcome, but very unexpected news reached me of the finding of another bone, described as being of the size of an ordinary Oxonian; and no time was lost in arranging for its preservation. It was found to be

[k] Proc. of the Ashmolean Society, Oxford, 1848.

lying on a freshly-bared surface of the Great oolite, nearly in the line of a natural fissure, and covered by the laminated clay and thin oolitic bands which there occupy the place assigned to the Bradford clay of Wiltshire.

Crushed beneath the heavy load—once far heavier, when some hundreds of feet of the strata had not been removed by denudation —forced down upon its rocky bed, the large bone was completely shattered in all the middle part, though scarcely altered in figure at the ends. The middle part was not originally hollow, as birds' bones are, but filled with a loosely-cancellated structure, which yielded without much difficulty, so that the cylinder of bone came to be greatly compressed, and split in various directions.

It lay quite alone, no other bone supposed to be near it. Examined with care, it was soon found to be, like the first discovered bone, a femur, and of the same side, but very much larger, being by measure sixty-four inches in length. When it arrived at the Museum, in fragments too numerous to count, one might well doubt if ever it could be refitted, but there were favourable circumstances. First was before us the example of successful perseverance in the fine restoration of Mr. Strickland's fossil; next we had the ends of the bone complete, or easily made so; a patient and skilful hand, that of my assistant, Henry Caudel, to adjust the chips; and plenty of recent skeletons of crocodilian and other reptiles in the Museum, under the charge of Dr. Rolleston, to keep right ideas in the mind. The restoration was the work of many tedious weeks, but it is as nearly as possible perfect.

While we were slowly readjusting the broken bone, the quarrymen continued their labours. A year passed, the bone was restored in all its grand proportions, and then another discovery was reported, which was the forerunner of more. The following notice, written after one of many visits to witness the extraction of the fossils, may be allowed to express the thoughts of those who beheld the amazing spectacle of huge bones lying on a floor of rock, as if placed by Art in a secret museum of Nature[1]:—

UNIVERSITY MUSEUM, OXFORD, *March* 22, 1870.

Since the discovery of the huge thigh-bone of this great lizard, about a year has passed in the slow working of the quarries, with no important additions beyond a few caudal vertebræ. Quite lately, however, notice reached me ('nostras pervenit ad aures') of several bones of large size, lying on or near to the surface of oolite where the great femur rested; and I have made several examinations of the locality and circumstances of the deposit. On the last occasion, my friend, Mr. James Parker, was with me, and gave excellent aid in the 'survey.' The space of ground in which the bones are found is apparently quite limited. They lie pretty near together, but not in their natural relative situations. All have been drifted, yet not so much as to have suffered by attrition, or mutual fracture. One may think the whole body of the vast old lizard, in the extremity of age, was here laid to uneasy rest; the parts separated by decay; the massive limbs disjointed, and the bones displaced. They lie in, or rather appear to constitute, a bone-bed, whose basis is clay, with abundance of carbonaceous matter and small masses of wood which has undergone 'eremacausis.' Selenite, the natural result of the mutual action of iron-sulphide and decaying wood, in presence of calcareous matter, is rather too abundant, and injures the firmness of the bones occasionally.

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[1] Athenæum, April 2, 1870.

Imagine a surface of the ossiferous clay which covers the oolite laid bare by the workmen. Look southward; before you are four bones laid rudely parallel, in a row, at intervals of 1, 2, or 3 feet. They are 64, 54, 45, and 37 inches long; 10 inches the least breadth in the narrowest part; 26 inches the greatest breadth in the widest part. These are bones of ceteosaurus. Over them and in front of them, three days since, lay as many others, as large and as quietly reposing in their 'longæval' graves; behind them, possibly, are still more bones, to be discovered at some future time. Bones of a much mightier area—probably hugest of all huge ilia—extended far and wide; vertebræ 8, 9, and 11 inches in diameter; monstrous ribs, of which the parts traceable and inferred are 59 inches long; and to this must be added two unknown quantities; so their length must have been $x+59+y$ inches: all this within the compass of a few square yards. It seems like the burial-place of the great father of lizards, each of whose bones demanded—but only some could obtain—a separate grave. To reconstruct the framework of bones by replacing the many hundreds of fragments (for they are all traversed by innumerable fractures, and can only be taken up in heaps of chips mixed with some large frusta) will be the work of many months in our Museum. There, it may be hoped, for many an age, 'dum stabit Capitolium'—while Parliament will let us alone—the student of ancient life will pause before the collected remains of perhaps the largest animal that ever walked upon the earth, and congratulate himself that he lives in mammaliferous not megalosaurian days—

> 'Et grandia effossis mirabitur ossa sepulchris.'

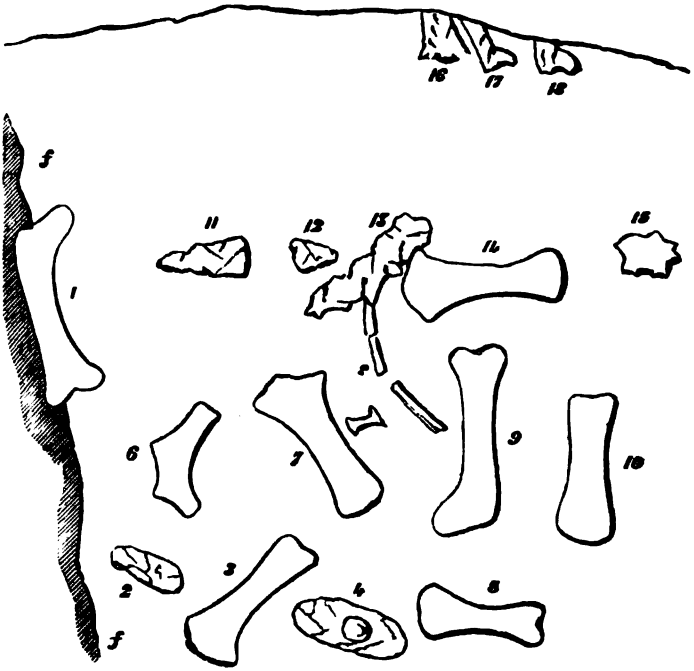

Diagram LXXXIV. Plan of the distribution of Bones of Ceteosaurus on the excavated oolite of 'Enslow Rocks,' at Kirtlington Station, north of Oxford, 1869–70.

1. Femur, discovered in February 1869.
2. Mass of bones in confusion. March 17, 1870.
3. Humerus. March 17, 1870.
4. Vertebra and bones in confusion. March 17, 1870.
5. Tibia. March 17, 1870.
6. Pubis. March 21, 1870.
7. Scapula. do.
8. Ribs, broken. do.
9. Femur. do.
10. Humerus. March 21, 1870.
11. Bones in confusion. May 16, 1870.
12. Bones in confusion. do.
13. Bones in confusion. do.
14. Scapula. do.
15. Coracoid. do.

16, 17. Broken bones and vertebræ. May 16, 1870.

18. Large vertebra. May 16, 1870.

ff. A continuous fissure.

A few days later, the anticipation expressed in the notice just given was fulfilled, and Dr. Rolleston and Mr. J. Parker were present to witness the exhumation of a scapula, pubis, and sternal and coracoid bones; and we completed a general plan of the 'ossuary'—a small space of ground within which to find so many and so large relics of ancient life.

The bones thus placed did not for the most part actually touch the oolite, still less were imbedded in it, though single examples occurred of each circumstance. The strata covering the solid oolite were thus noted, March 21, 1870:—

Thin skerry beds of Forest marble and shaly clay.	ft.	in.
Band of white calcareous concretions and clay	0	10
Blue and greenish clay with white calcareous spots, and selenite	2	7
Brown, yellow, and grey layers, argillaceous, sandy, and oolitic	1	4
Grey and argillaceous bed, with selenite	0	2
Grey and greenish bed loosely oolitic, with Terebratula maxillata, Avicula, Astarte	0	8
Clay and loosely-aggregated oolitic parts, with selenite and abundance of carbonized wood, some shells, and most of the bones	1	6
Clay below	0	6
Great oolite with undulated and water-worn surface.		

The two lower bands 'die out' to the southward, and there some of the bones came in contact with the rock, and others were engaged in it.

Besides the bones which are represented in the plan, the workmen took up several others in fragments, and many vertebræ, which have come to the Museum, and are now restored as completely as our full baskets furnished the materials. A census being now taken, we find that the 'Enslow Rocks' have yielded parts of three individuals, of three ages and sizes—the grandfather, father, and son. With them were found a few bones of megalosaurus, and one tooth of that animal. None of these animals have here furnished a head or any very intelligible part of one, as far as we have yet ascertained. It seems probable that in the former working of the quarry a good number of bones, which belonged to the second and third members of the family, have been destroyed—possibly the heads and cervical vertebræ may have suffered this misfortune. There remains, however, a small portion of unmoved ground yet to be examined [m].

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[m] Heads of teleosaurus are not infrequent at Enslow Bridge, and in beds of Great oolite below the strata containing ceteosaurus.

SYNOPSIS OF BONES OF CETEOSAURUS FROM THE GREAT OOLITE, IN THE OXFORD MUSEUM.

Parts of the Body.	Large Animal. Enslow.	Middle sized Animal. Enslow.	Small Animal. Enslow.	Vicinity of Chipping-Norton, &c.	Glympton, near Woodstock.	Buckingham.
Head	Unascertained bones, and part of one tooth.					
Cervical vertebræ						
Sternum	One	Portion.				
Coracoid	Pair.					
Scapula	Pair.					
Humerus	Pair		One	One, perhaps of a different animal.		
Ulna	Pair.					
Dorsal vertebræ	Several.					
Ribs	Several.					
Lumbar vertebræ	Few.					
Sacral	Unascertained portions.					
Ilium	A pair, nearly complete.					
Pubis	One.					
Ischium	One.					
Femur	Pair	One.				
Tibia	One		One.			
Fibula	One and portion		One.			
Metatarsal	Several, but not certain as to which size			Portions of a different animal.		
Phalanx	One found at an earlier date.					
Caudal vertebræ	Many			Several	Several	One.
Chevron bones	Several.					

Quite lately other specimens, vertebræ and foot-bones, obtained from the vicinity of Chipping-Norton, have been presented to the Museum by Mr. Neate, M.A., of Oriel College; and, to complete the history of our acquisitions, Earl Ducie has added a fine humerus found in the solid oolite, entirely free from compression, and almost complete. It is the more valuable, because of some sensible difference of form between it and the two previously dug up at 'Enslow Rocks;' for thus an additional argument arises in favour of the opinion, which for other reasons seems probable, that we have in fact, in the small range of estuarine and marine oolitic beds between Chipping-Norton and the Cherwell, remains of two gigantic animals, both as yet undescribed.

To these notices which I have collected of the discovery of bones of ceteosaurus in rocks of the Bath oolite series near Oxford, may be added vertebræ and other bones from Essendine near Stamford; several parts of the skeleton from Blisworth; a caudal vertebra from Stony-Stratford; and a vertebra and limb-bones in the Scarborough Museum, from beds of the same series on the Yorkshire coast.

In the neighbourhood of Oxford, however, other bones referred to ceteosaurus have been collected from Thame and Garsington, and will be noticed hereafter; in each of these cases it was the Portland rock which preserved them. I have heard also of others found in the same beds near Cuddesdon. At a greater distance from Oxford, and in deposits of another order—in the Wealden beds of Sussex—other remains of great reptiles referred to ceteosaurus occur. Thus, as far as we know, this genus was most conspicuous in, perhaps limited to, the oolitic period, for the Wealden may, in questions of this order, be justly regarded as the uppermost portion of the oolitic system, with which it agrees in containing megalosaurus.

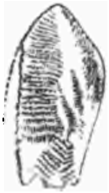

Diagram LXXXV. Tooth of Ceteosaurus. Scale size of nature.

Head.—As already observed, no well-ascertained bones of the head have yet been observed among the fragments found at any of the localities near Oxford. The tooth found at Kirtlington Station quarry is like that of an iguanodon in general shape (as far as can be known, one edge being broken), with a similar sweep of the concave surface, seen in the Diagram, and corresponding attenuation toward the edge. The edge is not serrated, but the striæ of accretion are so arranged as to suggest that it may have been. The opposite face of the tooth is broken.

Neck.—No certain specimen of cervical vertebræ or of their processes representing ribs has been recognized.

Trunk.—A considerable series of dorsal vertebræ and ribs, more or less incomplete, from the anterior and middle parts of the series, have been obtained from Kirtlington Station. The vertebræ have undergone various degrees of compression and distortion in different ways, so that it is only by examining many specimens that a consistent general description can be formed. In some cases lateral compression has produced an oval outline for the articular face, in other

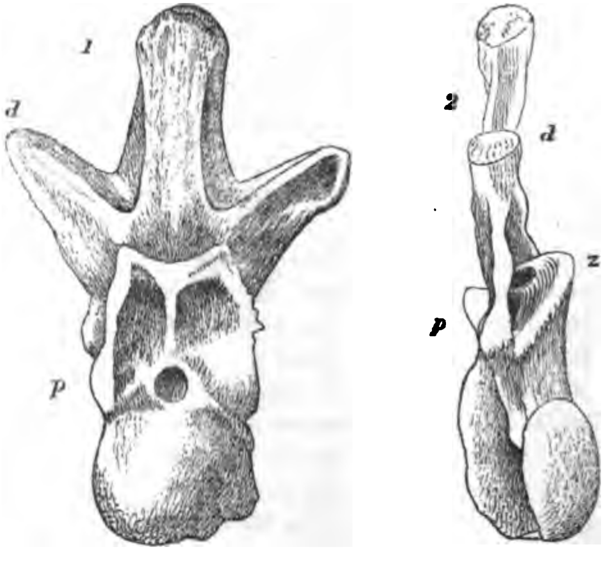

Diagram LXXXVI. Dorsal, probably the fourth Vertebra of Ceteosaurus.
Scale one-tenth of nature.
1. Seen endways, in front. 2. Seen on the left side. *d.* Diapophysis.
p. Parapophysis. *z.* Anterior zygapophysis.

cases the opposite sides have been forced into interference; occasionally the pressure has been endways, and the bone has become fimbriated or spread out like a fungus to more than its original diameter. The processes are generally broken off, and the fragments, probably by carelessness of the workmen, have been so confused and injured, that only one anterior dorsal vertebra has been reconstructed, and it is imperfect in the lower part.

This vertebra is represented in Diagram LXXXVI.

The dorsal vertebræ of our ceteosaurus are not constructed on the crocodilian type, except in their bearing double-headed ribs. The body is contracted in the middle, and deeply impressed under the rib-bearing process. The articulating faces are nearly circular, one concave, the other convex, but the crushed state in which they occur renders it often difficult to say which is anterior. In the specimen represented above the anterior face is convex, the posterior concave, but the outline of the body is incomplete and deficient of the whole border [n].

The diapophyses are strongly carinated, and directed upwards and outwards, so that if prolonged downwards they would meet centrally at a right angle; the neural spine, a broad vertical mass, is expanded laterally, and finishes in a thick massive subquadrate head, instead of forming a thin longitudinal blade, as in crocodiles. In these massive processes are cavities of considerable size; and in the angular shape of the bones, and a sort of buttressing observable in the arrangement, we seem to behold a structure of as much lightness as could be consistent with the required solidity.

The articulation of one vertebra with another is quite unlike in different parts of the vertebral series, and even in the dorsal series itself. The vertebra shewn is a forward dorsal, the parapophysis not being borne on the lateral spine. The zygapophysis appears to form a large concave sweep above, buttressed below at each end, and supported in the middle by a vertical ridge, which rises in a large hollow space above the neural canal. The anterior zygapophysis is not well shewn in this specimen.

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[n] *Streptospondylus.* Professor Owen mentions (Report on Reptiles, 1841, p. 88) a vertebra of this genus, or rather the anterior half of one, as being in the collection of Mr. Kingdon of Chipping-Norton, and found in the oolite near that town. It is an anterior dorsal, convex in front, with a deep lateral pit behind each of the costal articular surfaces: a portion of a spinous process, rugged and quadrilateral at the summit, accompanied the vertebra. This description seems to correspond to the anterior dorsals of our ceteosaurus from Enslow Rocks.

In vertebræ somewhat farther along the back (the parapophysis borne on the great lateral spine), the posterior zygapophysis is observed in two examples, from which a restoration is attempted in Diagram LXXXVII. on the same scale as the figure in Diagram LXXXVI.

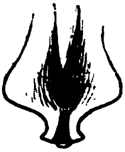


Diagram LXXXVII. Posterior zygapophysis of Ceteosaurus. Scale one-tenth of nature.

If this be compared with the corresponding part in megalosaurus in Diagram LIX., with that of Ceteosaurus brevis (Owen, on Wealden Fossils, Supplement I., 1857, Plate VIII.), and with that of streptospondylus (Plate VII.), a general analogy will appear, while all differ much from the crocodilian form.

The specimen figured (Diagram LXXXVI.) measures, in its crushed and incomplete state, 6·5 inches from back to front of the body; other examples of dorsals farther on, not so crushed as to conceal the length, give 8·5 inches. The diameter of the largest is 8·5, and the height is equal to the breadth; the outline being a little sunk under the neural canal.

The neural canal is 2·4 inches high, and two inches wide. The space between the neural canal and the zygapophysial articulation is 5·1 inches. In another specimen this space is 6·0 inches. From the base of the neural canal to the summit of the neural spine, 21 inches; distance between the summits of the diapophyses, 18 inches. From the base (incomplete) of the vertebra to the summit of the neural spine, 28·25 inches. The surfaces for the attachment of the ribs are at a distance of twelve inches. The most unusual features in these strange bones are the great broad head of the neural spine (several fragments are larger than this), and the high and wide hollow interspace between the neural canal and the anterior zygapophysis. Several other dorsals follow, none complete, one of which is represented on the next page.

What appear to be lumbar vertebræ are so much crushed as to be unfit for representation. They appear to be shorter (antero-posterior measure) than the dorsal vertebræ, but also of larger diameter, as the following measures shew:—

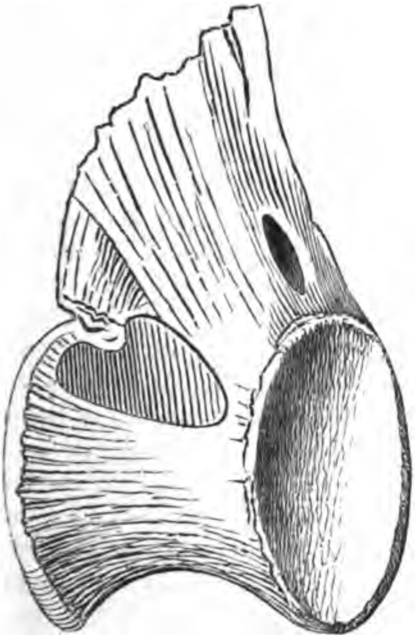


Diagram LXXXVIII. Ceteosaurus—Middle or Posterior Dorsal. Scale one-fifth of nature.

	inches.
Greatest length from front to back (crushed)	4·6
Greatest depth, below the spinal canal	9·0
„ by the side of canal	9·5
Greatest width	9·0
Spinal canal, vertically	2·0
„ transversely	2·0
From spinal canal, lower surface, to lower edge of zygapophysis, posterior process	2·5
Anterior face nearly plane, posterior concave	2·5

These vertebræ are so forcibly constricted in the middle through end pressure as to resemble a deeply-channelled pulley wheel. Their neural processes rise quite as high as in the anterior dorsals.

Sacrum.—Several bones of this portion are in the collection, but there is great difficulty in so placing them as to acquire a just notion of the structure, or to present a satisfactory drawing. In some degree it must have approached that of hylæosaurus.

Next to be noticed is the fine series of caudal vertebræ belonging to the large animal of Kirtlington Station. These are in number twenty-seven, besides some fragments not capable of being placed in order. Several of these have the neurapophyses, neural spine, and zygapophyses (seldom, however, perfect) still attached, and thus give means of comparison with crocodilian and other vertebræ in a characteristic part of the structure. The articulating faces are concave, the anterior often most so, or else concave in front, and plane behind.

Some of the largest are crushed, so as not to be fit for drawing.

Taking them in their probable order, we find the following examples. The first, only four inches from back to front, is 9·5 in height to the borders of the canal, 9·0 to the canal, and 8·5 in breadth. It is an extraordinary bone, having the transverse process occupying for its base a great part of the height of the side, and expanding outwards like a frill to a width between its broken edges of 13·5 inches; it must have reached 16 to 18 inches when perfect. Both ends of the body are pretty equally concave. No hæmapophysial cicatrices.

The next, as I suppose, is of the same diameters, and 4·5 inches long. The anterior side is most concave. The interspace above the neural canal is reduced to three inches. The lateral spine has a large basis. The hæmapophysial scars are slight. The anterior zygapophysis bends forward, its separate elements inclined about 60°.

Another follows, perhaps immediately, 8 inches across, 5 inches long, with strong lateral processes and more marked hæmapophyses. The anterior surface is concave, the posterior plane.

After this the vertebræ which follow become longer, and concave on both terminal faces, and the hæmapophyses are indicated by broad cicatrices, always most deep and extensive on the posterior edges.

One of these vertebræ (anterior caudal), which is uncrushed and contains the diapophysial processes, is represented on the next page. Its dimensions are—length between articulating faces, 5·5 inches; breadth of the faces, 7·5; height, 7·0; interval between the extremities of the diapophyses, 12 inches. The neural spine is broken; probably it rose twelve inches above the canal and was three inches broad; the zygapophyses are not to be completely traced; the posterior ones are shallow concavities, as in the drawing of Owen, Pal. Soc. Mem., Plate X. The articulating surfaces for the hæmapophyses are large and rough: both margins shew these, but chiefly the posterior, in which they are distinctly separate, in the anterior less so. There are several of these vertebræ less complete.

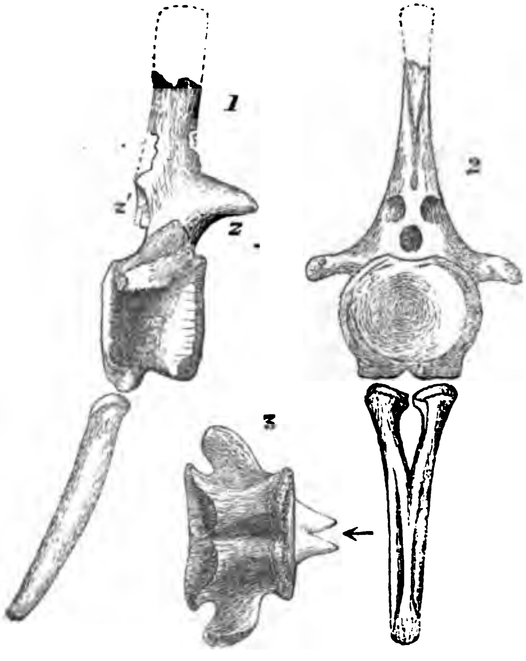


Diagram LXXXIX. Scale one-tenth of nature.

1. Anterior caudal vertebra of ceteosaurus, seen on the right side. 2. The same, seen from behind. 3. The same, seen from beneath. *zz'.* Zygapophysial processes. Hæmapophysial spines or chevron bones are seen below. The arrow points from the head.

Another vertebra removed farther back, so as to be nearly at half the length of the tail (retaining the reduced mark of the diapophysis), measures as under:—Length, 5·8 inches; breadth, 6·0; height, 6·5; concavity of articular faces, 0·5. The neurapophyses occupy above half the length; posterior space largest.

This vertebra has horizontal prominent ridges in the middle of the sides; the articulating faces are broadly reflexed and roughly bordered; the hæmapophyses separate and much reflexed on the posterior edge. Neural spine broken, more than three inches wide.

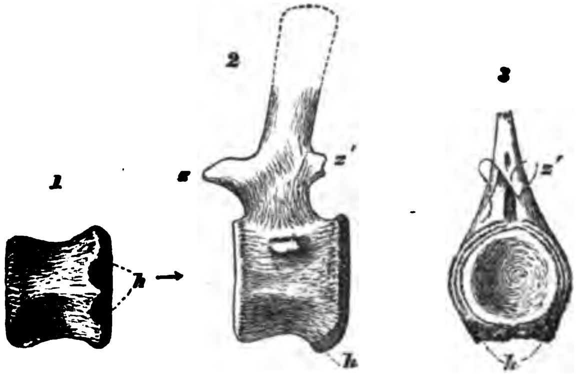


Diagram XC. Scale one-tenth of nature.

1. Premedial caudal vertebra, seen from below. 2. The same, seen on the left side. 3. The same, seen from behind. *zz'*. The zygapophysial processes. *h*. The posterior hæmapophysial surface. The arrow points from the head.

Zygapophyses, anterior, much extended, laterally compressed (*z*); internally nearly plane, slightly oblique; posterior, appear to be only elongated hollows on the neurapophysis (*z'*).

Beyond the middle of the tail, where all trace of transverse spine is lost, the lengths of the vertebræ are little or not at all reduced, becoming hour-glass shaped. The neural canal is covered for nearly half the length of the vertebra anteriorly; from this passes backward a long ascending process, which bears the posterior zygomatic articulating faces. See Diagram XCI.

The dimensions of this instructive vertebra are as under:—Length, 4·25 inches; breadth, 3·75; height, 3·3; depth of concavity of faces, 0·35.

Of chevron bones we have five specimens, from the anterior and middle portions of the tail. In Diagram LXXXIX. one is represented close to its place of attachment, on the posterior aspect; the two branches almost in contact. The length of this chevron is 14 inches on the median line, and the breadth over the branches 4·75. The whole vertebra, including the neural spine, would be 33 inches in height.

A larger specimen, measuring 5·4 inches in breadth, and originally 16·5 in length, belonged to one of the forward caudals, whose height equals 8, 8·5, and 9 inches. Such a vertebra complete must have

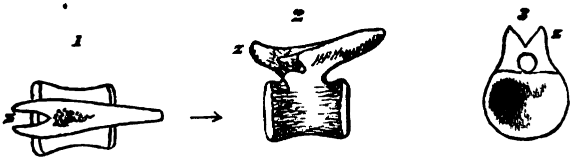


Diagram XCI. Scale one-tenth of nature.

1. Postmedial caudal vertebra of Ceteosaurus, seen from above. 2. The same, seen on the left side. 3. The same, seen in front. *z*. The anterior zygomatic processes. The arrow points from the head.

been not less than 36 inches, and not above 40 inches in height. The branches of this chevron bone touch and interlock; probably in the other the rami did touch.

The vertebræ referred to by Professor Owen from Chapelhouse, near Chipping-Norton (eleven, as stated in Geol. Proc. 1841, *loc. cit.*, or ten, as we find in Rep. Brit. Assoc., 1841), are recognized in the Oxford Museum, and agree in general with the description given of them. With one remarkable exception, however. The largest of the vertebræ is described as measuring 7 inches across the articular surface at each end of the body, and not less than 2 feet in vertical diameter, including the neural and hæmal spines (Brit. Assoc. Rep., 1841). Professor Owen mentions it as being in the collection of Mr. Kingdon, but it is not noticed in the abstract of his paper read to the Geological Society, *loc. cit.*

Some other vertebræ, of nearly the same magnitude as those which we possess from Chipping-Norton, and from the same part of the animal, were found at Glympton; and there is one whose place was near to the sacrum, larger than the rest, without locality assigned. The matrix is like that of Chapelhouse. Length, 5·25 inches; breadth of anterior face, 9 inches; of posterior, 8 inches; height to the neural canal, 7 inches; that canal something less than 2 inches in diameter, and nearly cylindrical. Anterior face deeply concave; posterior nearly flat, reflected on the lower margin for the articulation of the hæmapophyses. Sides of the vertebra concave between the expanded articular faces. Neural arch anchylosed to the corpus, and placed on its anterior part. Neural spine broken off above the canal; zygapophyses broken off; diapophyses also truncated. This appears to be one of the more forward of the caudal vertebræ; it is strongly marked on the posterior lower edge by the broad reflected articulating surface for

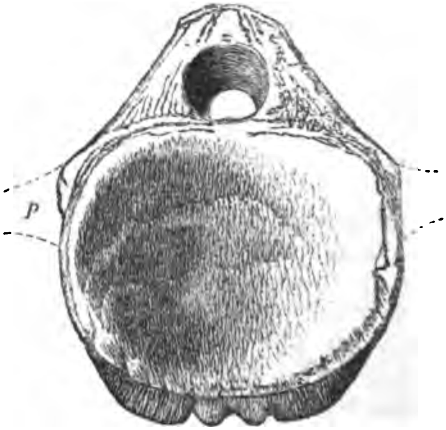


Diagram XCII. One-fifth of nature.
Anterior view of a large anterior caudal vertebra, probably from Chapelhouse.

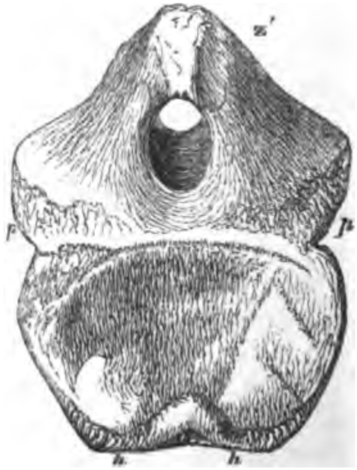


Diagram XCIII. One-fifth of nature.
Posterior view of a large anterior caudal vertebra, probably from Chapelhouse.

the chevron bones. Between these the lower side of the vertebra is somewhat channelled lengthways.

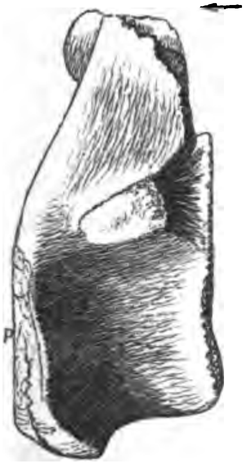


Diagram XCIV. One-fifth of nature.

Lateral view, right side of a large anterior caudal vertebra, probably from Chapelhouse.

The remaining vertebræ from Chapelhouse, ten in number, carry on the series to within some two or three of the end; having no diapophyses, and a partially uncovered neural canal. The following are the dimensions of these vertebræ in inches :—

Posterior Caudals.	Length of Centrum.	Breadth of Centrum.	Height of Centrum.	Least circumference behind Neural arch.	Anteneural space.	Neural arch.	Postneural space.
No. 1	5·0	4·6	4·6	15·0	..	..	..
2	5·1	5·0	5·0	14·0	0·5	2·75	1·75
3	5·6	4·2	4·6	12·0	1·1	2·5	2·0
Interval unknown.							
4	5·45	4·0	4·0	11·5	1·0	2·0	2·0
5	5·5	3·7	4·0	..	..	..	..
6	5·5	..	3·7	..	1·65	2·2	1·65
7	5·5	3·0	3·25	..	..	..	..
8	5·2	3·15	3·10	..	1·0	2·6	1·6
Interval unknown.							
9	5·0	2·6	2·6	..	..	..	..
Interval unknown.							
10	3·70	2·0	1·5	..	..	..	..

In this fine series, probably indicating fifteen or more posterior caudals, the articulating surfaces are nearly circular, and nearly of equal concavity; the body is contracted round the middle, so as to become hour-glass shaped; the space covered by the neural arch is about half the whole length (two cases are exceptional), the posterior uncovered part being usually much the largest. In No. 10 the body is distinctly arched.

Three of the vertebræ presented by Mr. Neate, from the same neighbourhood, have lateral apophyses, and must be regarded as of the anterior half of the tail. The largest has the two articular faces nearly equally concave; the bases of the lateral apophyses much extended horizontally. The others have these bases nearly round, and more elevated on the corpus.

The dimensions of these vertebræ are given below in inches.

	Length of Centrum.	Breadth of Centrum.	Height of Centrum.	Least circumference behind Neural arch.	Anteneural space.	Neural arch.	Postneural space.
No. 1	5·0	7·4	6·5	22·0	0·5	3·6	1·5
Interval unknown.							
2	5·1	6·5	6·1	17·7	0·7	2·8	1·5
3	5·8	6·4	5·8	19·0	0·7	2·6	1·5

The vertebræ from Glympton, all posterior caudals, have both faces in some degree concave (less so than in the Chapelhouse series); the posterior most concave; the anterior largest. The neural arch is nearer to the anterior face. The following are their dimensions in inches:—

	Length of Centrum.	Breadth of Centrum.	Height of Centrum.	Least circumference behind Neural arch.	Anteneural space.	Neural arch.	Postneural space.
a.	6·3	4·8	5·1	..	1·0	3·5	1·7
b.	6·45	4·4	4·9	..	1·0	3·6	1·8
Interval.							
c.	Frustum of anterior part.						
d.	Frustum of anterior part.						
Three intervals.							
e.	Frustum.						
f.	Frustum of posterior part.						
g.	6·1	2·9	3·0	..	0·7	3·7	1·5
h.	5·85	2·95	2·7	..	0·8	3·6	1·4
i.	5·7	2·65	2·5	..	0·7	3·6	1·3

In this series the first (*a*) has the body contracted and subprismatic by the formation of three lateral facettes; a large, oval, vertical foramen in the neural canal, behind the centre. It may be regarded as occupying a place corresponding to the 18th in crocodile, 37th in iguana, 65th in monitor. A narrow vertical foramen is remarked in the neural canal of *b*. At *g* the body becomes hour-glass shaped. These vertebræ are obviously longer than those from Chapelhouse; on the average by an inch, while the diameters are not materially different.

The fine vertebra from Buckingham, already mentioned as represented by an excellent cast, was not far from the beginning of the tail, and shews the diapophysis prominent about an inch. The length is 6·0 inches; the height 6·0; the breadth 7·0. The articulating faces are concave to the depth of 0·4. The lower edges are revolute; the posterior much so, with divided hæmapophysial cicatrices. The neural canal is contracted in the middle to half an inch, but expands towards each edge. The neural spine is broken off. This vertebra may be regarded as next in front of that represented in Diagram XC.

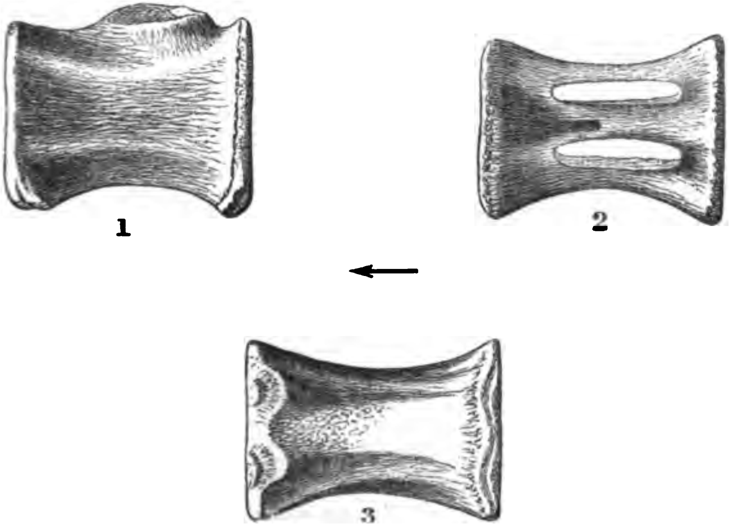


Diagram XCV. Middle Caudal Vertebra of Ceteosaurus, from Glympton. One-fifth of nature. 1. Seen on the right side. 2. Seen from above. 3. Seen from below.

From what has been said, it is apparent that the caudal vertebræ of ceteosaurus have no particular affinity with those of crocodile, except in the diapophyses and neural spines. The bodies of the vertebræ are different, especially in the posterior part of the tail, where the hour-glass shape is significant of quite other kindred. And in respect of the processes referred to, the resemblance is not great. The diapophyses are subcylindrical or conical, instead of being flat plates; and, in the latter part of the tail especially, the excurrent neurapophyses are of quite a different character.

To those caudal vertebræ of the Wealden, which have been referred to pelorosaurus and ceteosaurus, the resemblance of our Oxonian fossils is much closer. The four anterior caudals, figured by Mantell as median caudals of pelorosaurus (Phil. Trans. 1850, Plate XXII.), agree in a general manner with ours from the same part of the tail, but are much shorter, and more quadrate: the zygapophyses differ, but the chevron bones agree in being disunited proximally.

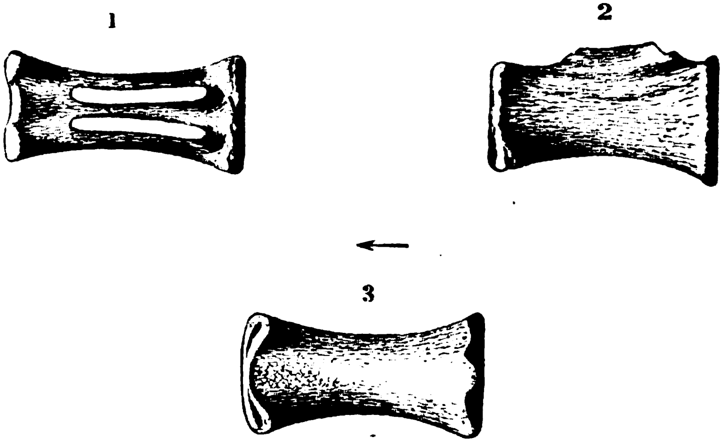


Diagram XCVI. Posterior Caudal Vertebra of Ceteosaurus, from Glympton. One-fifth of nature. 1. Seen from above. 2. Seen on the right side. 3. Seen from below.

Still more considerable is the agreement of one of our (posterior) caudals, Diagram XCI., with the curious vertebra described as 'median caudal' of pelorosaurus (Phil. Trans. 1850, Plate XXVI.). The cylindrical form of the anterior zygapophysial processes in the Wealden fossil, and their great forward projection, make a difference: in our specimens these processes are not so different from the pattern of the anterior vertebræ. Our vertebræ from Glympton are about one-fourth longer. In Professor Owen's account of Ceteosaurus brevis of the Wealden, he gives to that species the fossils above noticed by Mantell as pelorosaurus.

Ribs belonging to some ten or a dozen vertebræ were found, but none complete. Indications were obtained of a length of five feet, and an interval of the articulating heads of one foot.

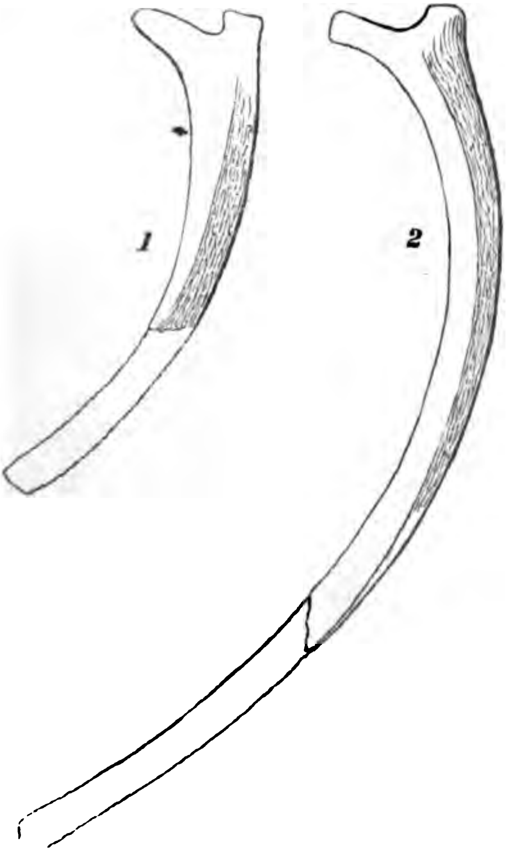


Diagram XCVII. Ribs of Ceteosaurus. Scale one-tenth of nature.
1. Anterior. 2. Middle dorsal.

Shoulder girdle and fore-leg.—For a considerable time in the course of the digging there seemed reason to fear that no parts of the animal but those behind the back would be brought to light. In the progress of the excavations, however, the interesting bones now to be mentioned, viz. sternum, coracoids, scapulæ, and humerus, came to be observed; and when all the spoils collected by the workmen came to be studied, several specimens of importance were added; viz. a pair of ulnæ of the great animal, and one humerus of the small individual.

Sternum.—A broad, slightly-undulated plate, of transversely-elliptical contour, emarginate in front, running out into processes behind, with lateral facettes for the apposition of the coracoids, furnishes the central support for the shoulder-girdle of ceteosaurus. In Diagram XCVIII. the bone is seen internally, 19 inches broad (if complete), 15 long, and 2¼ thick at the coracoid junctions. These junction surfaces are inclined 45° to the plane of the bone; those of the coracoids about 75°: from which it follows that the bones must have been inclined to each other 120°; and the general

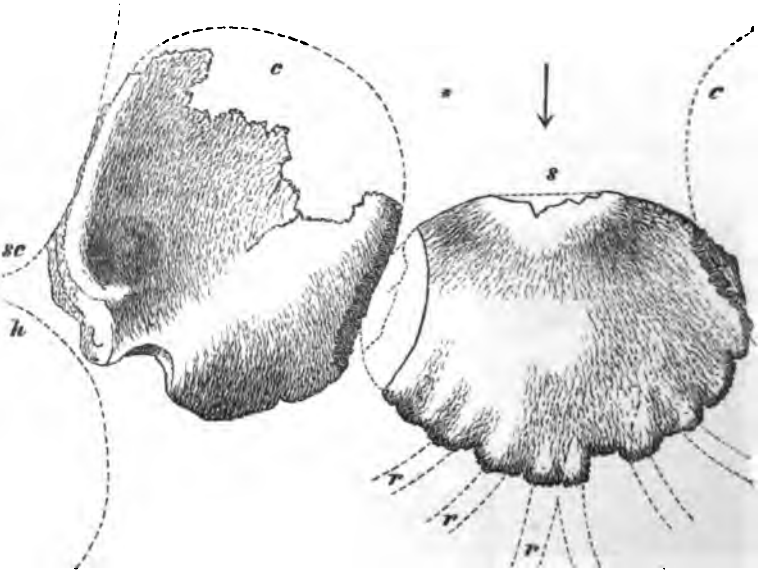
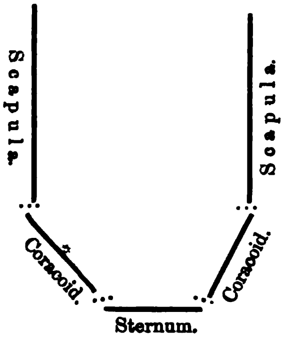


Diagram XCVIII. Sternum of Ceteosaurus. Scale one-tenth of nature.

Sternum of ceteosaurus (*s.*); in relation to the coracoids (*c. c.*); as one of these is to the scapula (*sc.*), and humerus (*h.*). The sternal rib-junctions are marked *r*. The drawing is made from separate specimens of the bones, the allocation being a matter of inference. It is supposed that the bones are seen by looking down (or internally) on the sternum; the coracoid in the same plane as the sternum, to give its shape, and not inclined, as it was in the body. It is supposed that the middle retral prominence of the sternum carried a divided rib, as in monitors.

relations of the scapulo-sternal arch would be as below, giving 36 inches as the space between the lower ends of the scapulæ.



The mode of implantation, or rather of apposition, of the ribs to prominences on the posterior border, is like what occurs in iguana: the fewness of the side rib-junctions (two on each side, or possibly three) reminds us of the monitors and crocodiles, which have two, rather than of iguana, which has four. The transversely-elliptical figure of the whole bone is without example among living reptiles[o].

There is a portion of a second sternum, smaller than that above mentioned, and apparently agreeing in magnitude with the middle-sized femur made known by Mr. Strickland.

Coracoids.—A pair of these bones occurred at Enslow Rocks, and but for the awkward position in which they lay, and the thinness of some parts, might have been extracted entire. In Diagram XCVIII. the least injured is represented, and a dotted outline is added to complete the figure. It is supposed to be seen internally, the arrow flying from the head. On this aspect it is largely concave, with a prominent convex wave directed backward and outward. The articulating surface making part of the glenoid cavity is rough and deep; the borders are thickened all round, and against the sternum bevelled to 70° or 75°, but against the scapula nearly square. There is a deep, smooth sinuosity behind the glenoid articulation, but no perforation of the disk of these coracoids. On the opposite surface of the bone a broad convexity corresponds to the concavity on this. The junction lines with the scapula and sternum are nearly parallel. The dimensions are as follows:—Length from glenoid cavity to the extremity of the bone near the

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[o] The admirable volume on the Shoulder-girdle and Sternum, by W. K. Parker, F.R.S., issued by the Ray Society, may here be consulted with advantage.

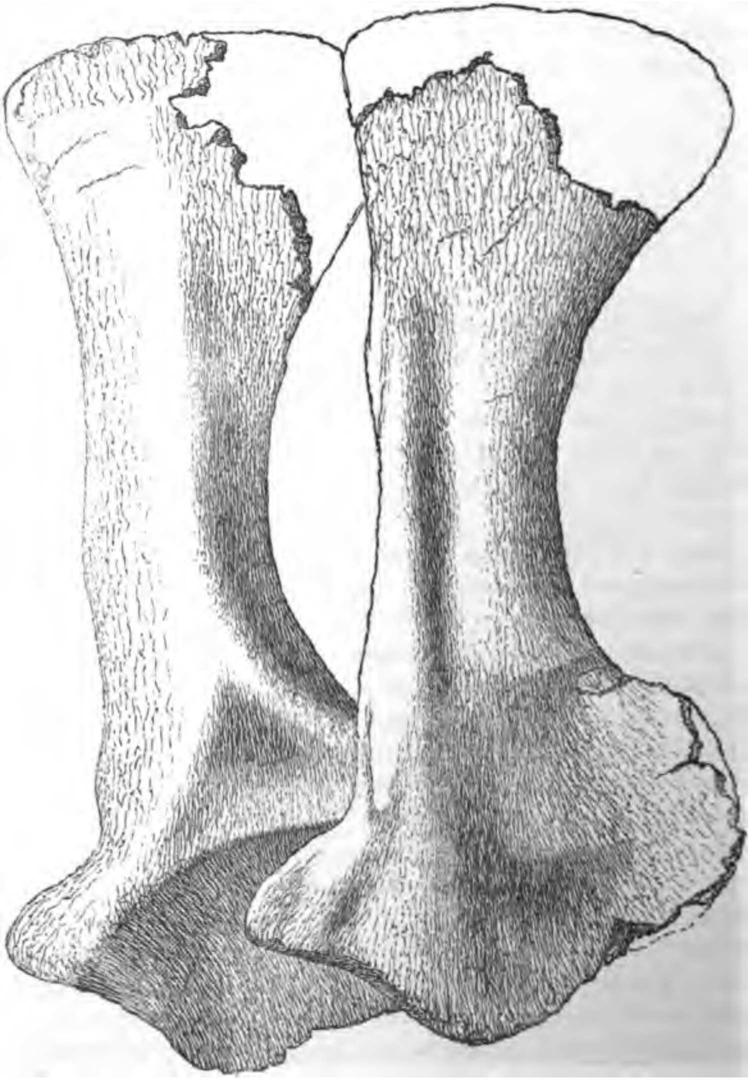

Diagram XCIX. Scapulæ of Ceteosaurus. Scale one-tenth of nature.

scapular margin (incomplete), 18 inches; if complete, probably 20; breadth between scapular and sternal margins, 18·5 inches; greatest thickness, 5·0.

The two bones are not quite alike; one is much thicker toward the anterior margin, and seems to have had a deeper and narrower sinuosity behind the glenoid surface, but it is much crushed in that part.

Scapula.—A pair of these fine bones, belonging to the great ceteosaurus of Enslow Rocks, was carefully dug up; and, as well as the thinness and feebleness of parts of the bone allowed, both have been restored. The length is 54 inches; the breadth where greatest, near the coracoid, 26; where least, at about half the length, 10 inches in one, and 9 inches in the other; near the upper edge, now broken away in each case on the anterior side, when complete, 20 inches. The upper part of the bone, for a space of 3 inches, has a peculiar structure, which seems to have been cartilage incompletely ossified. The outline is very concave on the anterior edge for two-thirds of the length; then it becomes convex in a semicircular curve; the posterior edge is undulated, but on the whole almost straight to near the glenoid cavity, which has a prominent upper border. The upper edge is truncate, the lower projects in the middle.

The surfaces, nearly plane in the upper part, become undulated below; on one side the middle is convex for half the length (see left-hand figure in Diagram XCIX.); from this point the convexity subsides, and is replaced by a diverging depression, which presently is followed by a broad, even concave sweep, reaching to the lower edge. This is supposed to be the outer surface.

The other side is ridged parallel to the posterior edge, the ridge continuing to the border of the glenoid cavity; towards the anterior edge the bone is rounded in the middle, and undulated and broadly depressed in the lower part (see right-hand figure, Diagram XCIX.).

It is somewhat difficult to determine the external and internal sides of this bone, for it differs materially from other known scapulæ. There is a delusive resemblance to the corresponding bone in the crocodile.

Humerus.—A fine pair of these bones belonging to the larger animal, quite complete, shews as great a difference in proportion

from the corresponding part of megalosaurus, as we have found in the scapula.

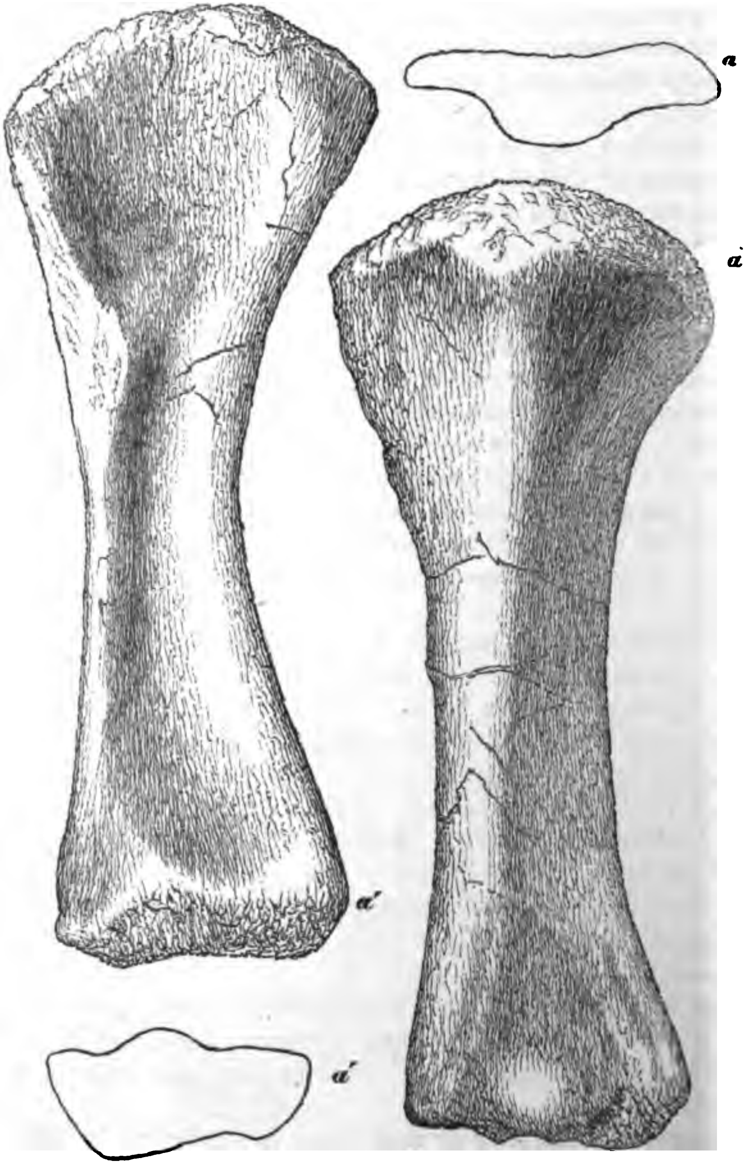

Diagram C. **Right humeral bones of Ceteosaurus. Scale one-tenth of nature.**

The left-hand figure represents a right humerus, seen on the front (or, in the crocodile, lower) face, shewing the deltoid crest. Below is the outline of the lower end, *a′* marking the corresponding points.

The right-hand figure is taken from a left humerus, seen on the posterior (in crocodile, upper) face. Above is the outline of the upper extremity, the letter *a.* marking a corresponding position.

The dimensions are as follows:—Extreme length, 51·5 inches; extreme breadth, upper, 20; lower, 15; greatest depth, upper, 7·5; lower, 7·0; diameters at the middle of the shank, 8·5 and 4·5.

One example of a humerus of the young ceteosaurus has occurred, and is represented in the Diagram below.

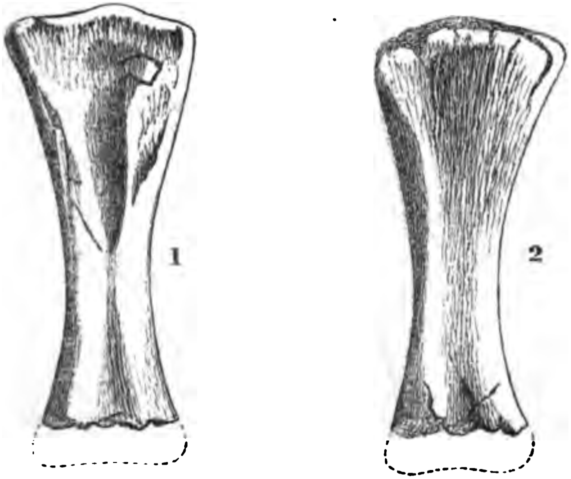

Diagram CI. **Left Humerus of the small Ceteosaurus, on a scale one-tenth of nature.**

1. Seen in front, shewing the deltoid crest. 2. Seen behind (above in crocodile). The distal extremity incomplete.

The dimensions of this bone are as follows:—Length, 21·75 inches (if complete, probably 24); breadth of proximal end, 10 inches; of distal end (incomplete), 7 inches; diameters of shank, taken where it is smallest, the cross section being oval, 4·25 and 2·5 inches.

To complete our views of the humerus, the fine specimen presented by Earl Ducie may be represented below. It is somewhat less bulky and a little shorter than those from Enslow Bridge.

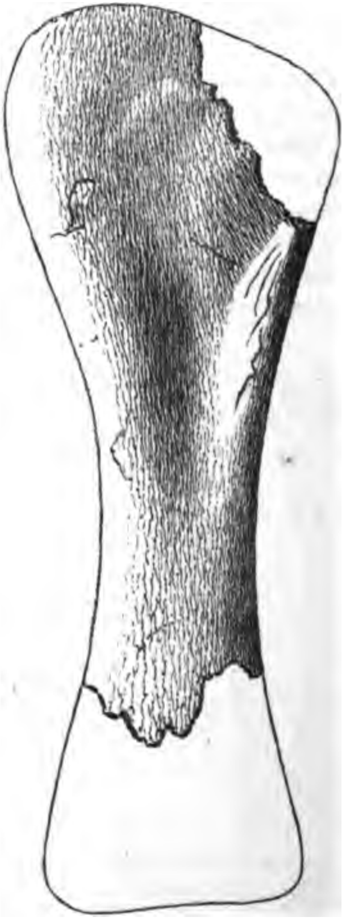

Diagram CII. **Left Humerus of Ceteosaurus, from Smith's Quarry, Sarsden. Scale one-tenth of nature.**

The bone was broken before being imbedded in the rock, and the lower end was somewhat smoothed, as if by attrition in water. The upper part was in some degree wasted and thinned by exposure to similar agency, but the figure of the bone is not materially altered by compression. Length of the fragment, 38·75 inches; probable full length, 48 inches; diameter where least, 8 inches; girth at the same part, 21·5 inches.

Ulna.—A pair of remarkable bones, somewhat pyramidal in shape, with an approach to a three-sided section, was obtained by the workmen at a time when we were not present.

Regarding them as ulnæ, the shaft is in some degree trihedral especially toward the proximal end, where the sides may be taken

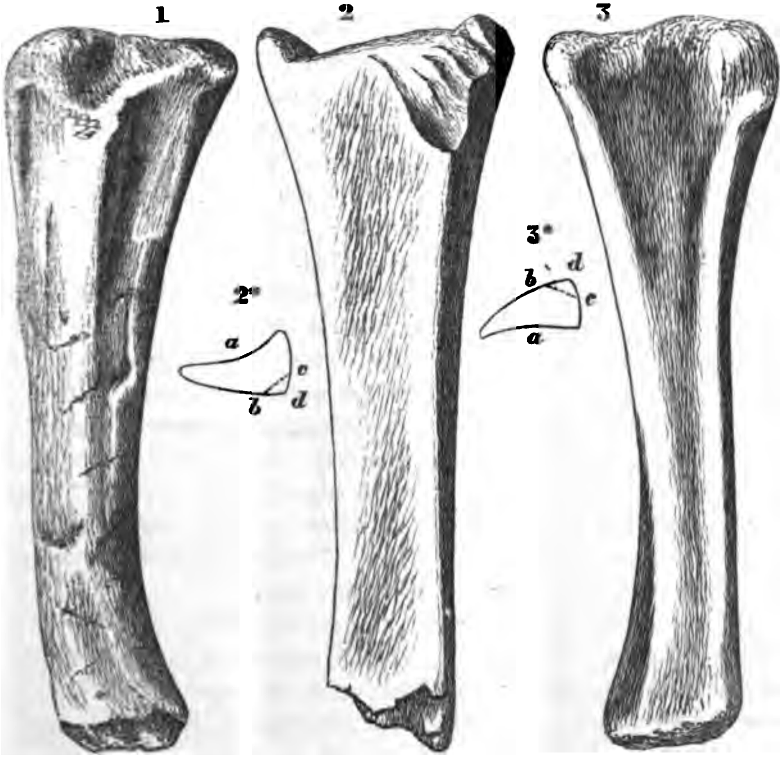

Diagram CIII. Ulna of Ceteosaurus. Scale one-tenth of nature.

1. Shewing the faces, *b* and *c*, and the truncation at *d*. 2. Bone of the opposite side, shewing the same faces less crushed at the truncation. 3. Shewing the face, *a*, of the same bone as fig. 1. 2*. The cross section of the bone fig. 2. 3*. The cross section of the bone fig. 3.

as *a* 12, *b* 11, and *c* 7 inches. The broadest side is there deeply and widely hollowed (fig. 3); it meets the other broad face in a rather thin expansion, and forms with the narrowest side a solid mass, which, however, is (in both specimens) truncated at the angle marked (*d*) in fig. 1. and fig. 2. This truncation, where the narrow face meets that of middle breadth, seems to be partly original and partly the effect of accident.

The bone is 38·5 inches long, a little arched, and toward the smaller end a little twisted (figs. 1. and 3), so that the longest diameter of that end, 7 inches, lies obliquely to the rest of the bone. The shorter axis there is 5 inches.

The pelvic girdle of the great reptile we are studying was formed on a scale of grandeur somewhat difficult to realize. We possess several bones which for some time were not at all clearly understood: after much thought, and frequent comparisons of them with skeletons of crocodiles and lizards, I arrive at the conviction which is expressed in Diagram CIV. Half the pelvic girdle is there drawn, as it presents itself to my mind, looking at the body from beneath, the arrow flying from the head. The upper bone is the pubis, measuring 38 inches between the extremes, with a breadth of 15 inches in the middle, the greatest thickness 4 inches. The whole is formed upon an arch; the inner or posterior edge is on a uniform curve, from which rises the medial symphysis *s s*, while the other end is truncated to meet the ischium, at *a*, and form with it the lower part of the acetabular socket. In this bone is an oval foramen, *f*. The outer or forward edge has three facets; that near *f* receives a process of the ilium, so that three junction surfaces are recognized in the bone. The general figure is nearly flat, with sweeping convexities along the middle.

On comparing this bone with the corresponding part in fossil reptiles, it is apparent that no special analogy is to be seen with ichthyosaurus or plesiosaurus, teleosaurus or megalosaurus. Some resemblance may be allowed to the pubic bones of living chelonians, which vary considerably: very little definite likeness can be traced when the comparison is made with crocodiles; but closer and more satisfactory affinity appears when we place together a reduced drawing of the huge pelvic arrangement of ceteosaurus and the tiny structure of a living monitor. Taking, for example, Regenia ocellata, of which a fine skeleton is in the Oxford Museum, we perceive a striking similitude; see Diagram CIV. fig. 3.

The small drawing referred to shews how much alike are the little and the great bone—similar concave sweep behind, similar facets in front, corresponding symphysial terminations, a foramen in the disk.

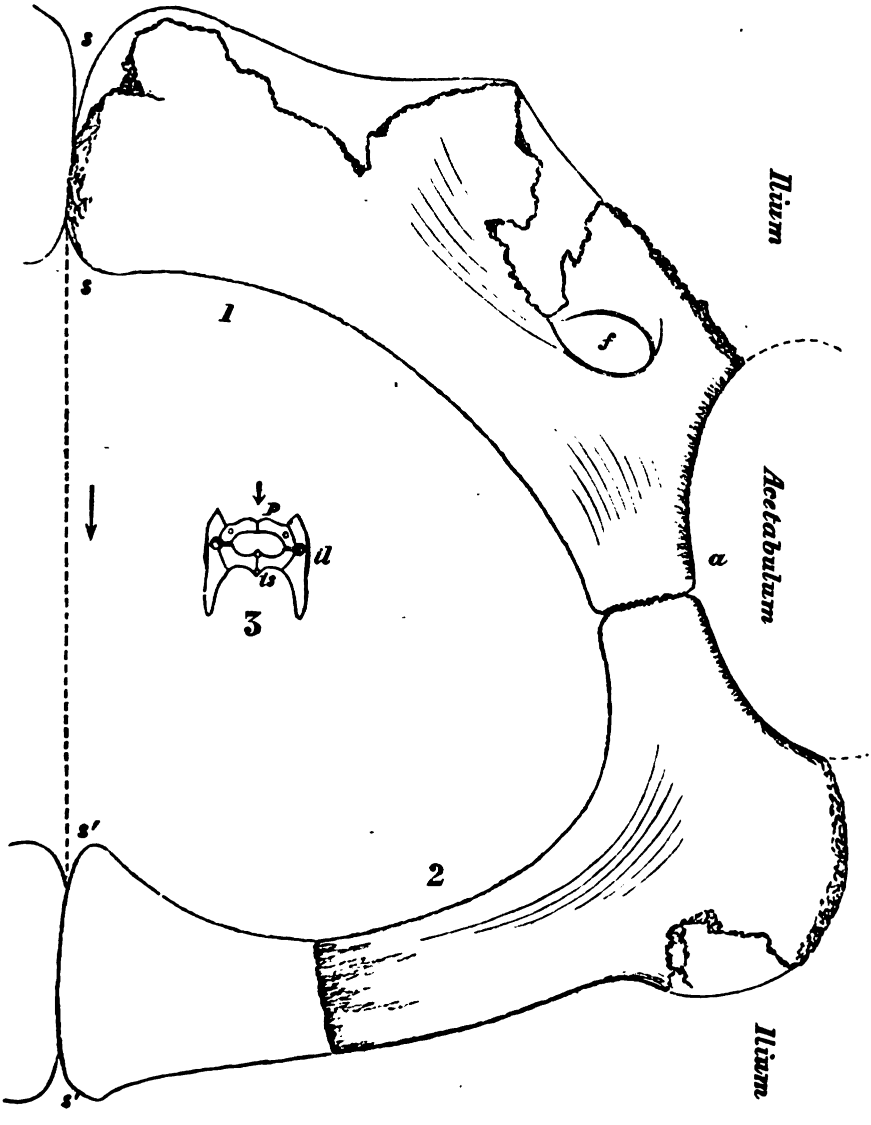

Diagram CIV. Pelvic girdle of Ceteosaurus. Scale one-tenth.

The pubis (1) and ischium (2) are represented on one plane, to shew the true figure of each. The ilium is marked by words only, to shew its position in a general manner. The ischial bone is incomplete at the medial symphysis *s' s'*. The pubis is only incomplete along the anterior edge; it was complete while in the ground. *f.* The foramen. *s s.* The symphysis. *a.* The junction of pubis and ischium, to form the inner and lower border of the acetabulum. 3. Pelvic girdle of Regenia ocellata.

The comparison thus made is supported by the other element of the pelvic girdle represented in the same Diagram by fig. 2—the ischium. This bone is complete except in the part near the medial symphysis, which is sketched at *s' s'* from general analogies. Its anterior edge is a deeply concave curve opposed to that of the pubis, with which it makes contact in a line directed to the middle of the acetabulum. From this line the acetabular curve, matching that of the pubis, curves outward to the rough surface which formed the attachment to the ilium. In all this the bone is like the ischium of the monitors; and probably both it and the pubis were attached to the ilium, much as they are in the well-known lizard, Varanus niloticus. The small accessory pieces of a lozenge figure which are seen in Regenia to extend the symphysis, have not been observed in the fossil.

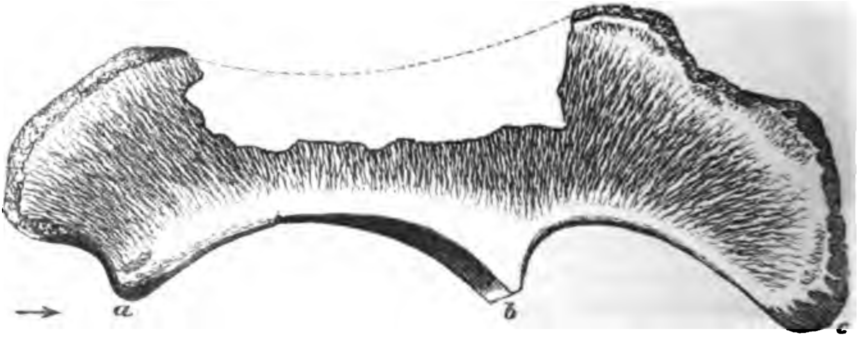

Diagram CV. Ilium of Ceteosaurus, seen on the external face. Scale, one-tenth of nature. *a b.* The acetabulum.

With great difficulty the separated parts of one ilium were first refitted, with the exception of the upper and middle portion of the bone. Then a second specimen, of the opposite side, was adjústed, both awkwardly crushed. The extreme length of one is 42, of the other 45 inches, probably equal to six vertebræ; the chord of the acetabular socket is 18; from the angular boundary of this socket, across the blade, the greatest width (or height) is 17; from the other extremity of the socket, a similar measure gives 14. The thickness of the bone is, in general, not above 4 inches, thinner in the middle part, without radiating ridges, but greatly thickened at one limit, and through a considerable part of the acetabular socket.

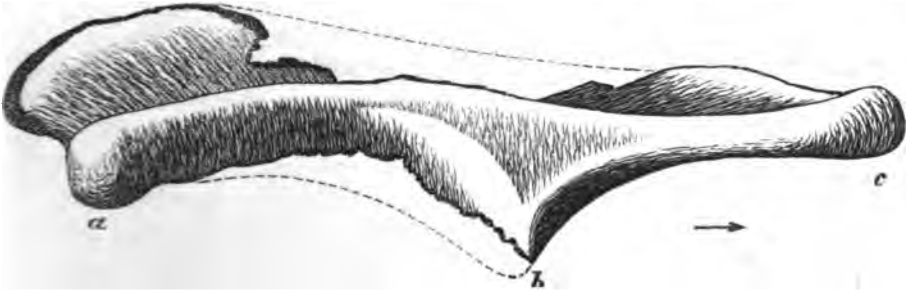

Diagram CVI. Ilium of Ceteosaurus, seen edgeways. Scale, one-tenth of nature.

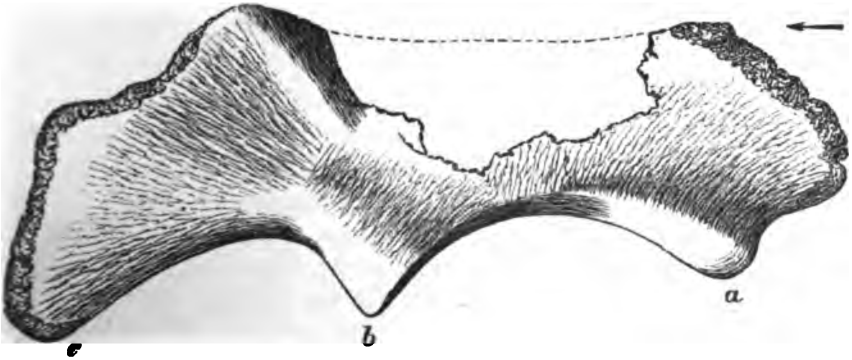

Diagram CVII. Ilium of Ceteosaurus, seen internally. Scale, one-tenth of nature.

Of the hind limbs of the great ceteosaurus the Oxford Museum contains two complete femora; one complete tibia, and part of a second; two fibulæ; several metatarsals, entire except as to epiphyses—these are from one individual; dug up at Enslow Rocks. From the same locality one femur, of a smaller animal; one long bone, and one metatarsal, probably of different individuals. There are also a few bones of a much smaller animal of the same genus, and probably of the same species, from the same place.

Femur No. 1.—Length, 51 inches; extreme breadth of the upper part of the bone taken obliquely, 17 inches; circumference of the same, it being compressed, about 36 inches; diameter of the smallest part of the bone, 8½ inches; circumference at the same part, much compressed, 21 inches; extreme breadth over the condyles, 14·5 inches; circumference at the same part, 37 inches.

The bone belonged to the left leg; its hinder surface is presented for observation. The bone is nearly straight, in this respect differing much from the crocodilian, and approaching toward the deinosaurian type. The expansion which corresponds to the great trochanter does not rise to the level of the head; there is hardly a distinct neck, but yet a marked interspace between the head and the trochanter, and a great inward flexure of the outline below the head (left-hand figure in Diagram CVIII.).

The shaft of the crocodilian femur may be described as twisted through about 60°, so that the plane of compression of the head makes this angle with the plane passing through both condyles. This does not appear to have been the case with ceteosaurus; all the specimens in our Museum have these planes nearly parallel, and this can hardly be attributed to the pressure which they have sustained.

The head of these bones is formed on a continuous sweep into the trochanterial surface in the crocodile; not so in ceteosaurus, which in this respect more resembles the ordinary deinosaurian type. The condyles are like those of crocodile and megalosaurus.

The pair of large femora have a length of 64 inches; breadth of the upper part, taken obliquely, 20·75 inches; circumference of the same, 46·0 inches; diameter of the smallest part of the bone, 11·125 inches; circumference at the same part, 27·5 inches; extreme breadth over the condyles, 17·5 inches; circumference at the same part, 44·25 inches. (Diagram CVIII., right-hand figure.)

These are by much the largest limb-bones of any known saurian, the nearest approach being the humerus of pelorosaurus, in the British Museum, from the Wealden, almost 54 inches long; the largest femur of megalosaurus being 42 inches.

Placed near to the corresponding femur of ceteosaurus, this large megalosaurian bone is like a child by the side of a giant; yet it is three times as long and as large as the femur of the largest crocodile.

The specimen is from the left side, and is mounted to shew the

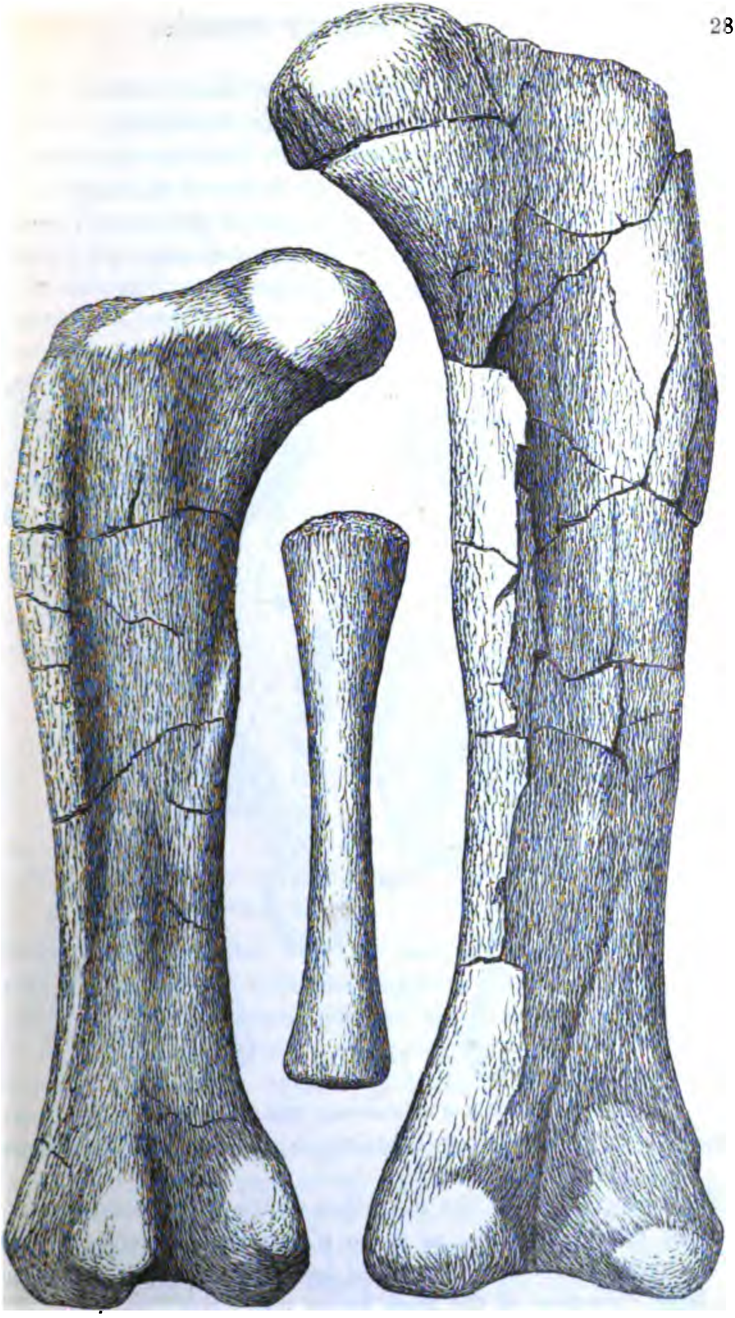

Diagram CVIII. Femora and Fibula of Ceteosaurus. Scale, one-tenth.

The left-hand figure represents the specimen found in 1848; the right-hand figure that found in 1868; in the middle a small fibula found in 1848 is shewn.

anterior face of the bone. It corresponds exactly, except in magnitude, with the specimen presented by Mr. Strickland.

Tibia.—One complete specimen of this bone has been obtained, of a size corresponding to that of the femur of the large animal, but unexpectedly short. Its extreme length is 38·5 inches; greatest breadth near the upper end, 17·0; at the lower end, 12·0; greatest thickness, lower end 6·75, upper end 5·75.

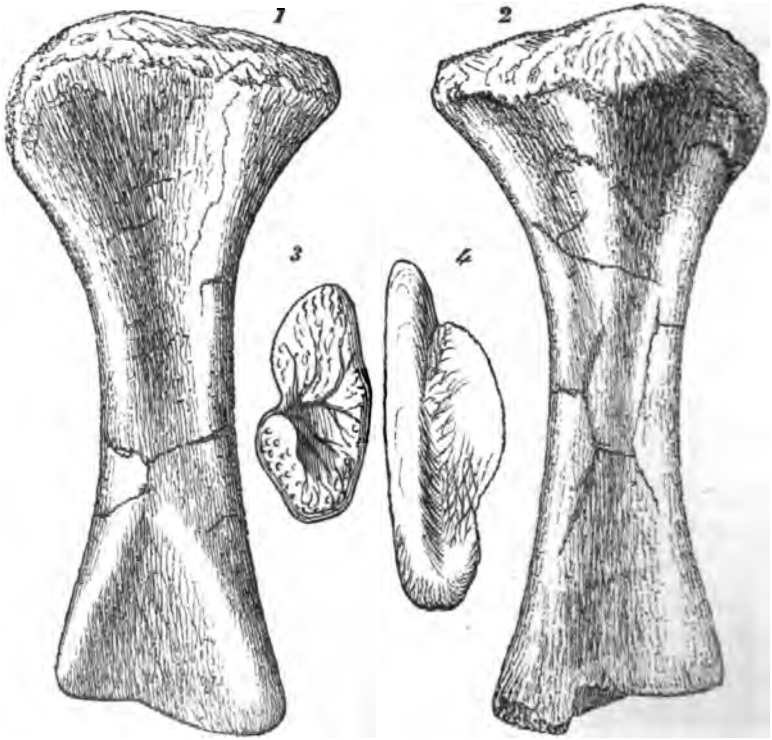

Diagram CIX. Tibia of Ceteosaurus. Scale, one-tenth of nature.

1. Seen in front, right side. 2. Seen from behind. 3. Lower end. 4. Upper end.

The bone is not so like any other of the deinosaurian type, or like the crocodile's tibia, as to be placed at once without doubt in the right aspect as to front and back. It is but little twisted, the long diameters of the ends being not much divergent. The terminal surfaces are strongly marked by the pitted adherence of cartilage—a constant fact in all the long bones—which gives the appearance of deficient epiphyses.

The lower part of the bone, on the front, is marked by a triangular depression, much as in megalosaurus, but not so sharply defined. The corresponding part in a crocodile is convex, and gives the idea of the ascending process of the astragalus being separated from its base and anchylosed to the tibia; while in megalosaurus the connection remains, and the ascending process is not joined by synostosis to the tibia. In this way of regarding the bone, ceteosaurus would be allied to megalosaurus, and not to crocodile.

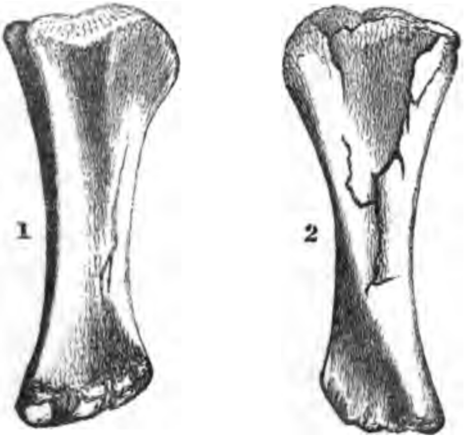

Diagram CX. Tibia of young Ceteosaurus. Scale, one-tenth of nature.
1. The view from behind, right side. 2. The view from the front.

One specimen of tibia has also been obtained from a young animal, corresponding with the humerus already noticed. It agrees in all essential points with the larger bone, but has yielded more to pressure, and is less complete at the lower end. Length, 21·25 inches; breadth, upper 9·5, lower 6·25; greatest depth (crushed), 3·25 (Diagram CX.).

Small Fibula—Length, 26·75 inches; breadth at the wider end, 6·5; in the narrowest part of the shank, 3·0; at the smaller extremity, 4·9. This bone is of a nearly symmetrical form, rather slender, and compressed. It shews no protuberances or asperities; the two terminal faces are nearly parallel, and the smaller is of a flat oval figure; the other curved, to fit the hollow surface of the bone.

It was found with femur No. 1, and is represented in Diagram CVIII.

Regarded as a fibula, it seems rather too short for even the middle-sized femur of ceteosaurus, but much too long for the smaller animal.

Another bone, in good condition regarded as a fibula, bears rather a greater proportion to the femur of the large animal, than the smaller specimen represented in Diagram CVIII. to the middle-sized individual. It has the same general aspect and characters, but is rather more curved at the larger extremity. Its length is 37 inches, somewhat less than that of the tibia to which it probably belonged; the breadth of the extremities about 11 and 8 inches; greatest thickness, 3 inches.

One side is concave for a great part of the length, the other convex. The bone is but little twisted, so that the long diameters of the terminal faces are not much out of parallel. There is a portion of a second of the same size.

Metatarsal.—Length, 11·20 inches; breadth at one end, taken obliquely, 5·5; at the other end, 4·75; in the middle of the shank, 3·25.

The first notice of this bone is in Dr. Buckland's Bridgwater Treatise, 1st ed. 1836, already referred to :—'There is in the Oxford Museum an ulna from the Great oolite of Enstone, near Woodstock, Oxon, which was examined by Cuvier, and pronounced to be cetaceous; and also a portion of a very large rib, apparently of a whale, from the same locality[p].'

In the second edition, 1858, we find added to this note :—

'These fossils belong to a large whale-like reptile, the *Ceteosaurus*. R. Owen.'

Professor Owen had already expressed this opinion in his Report on Reptiles to the British Association, in 1841, calling it a 'metatarsal of ceteosaurus.' It has but little resemblance to any of the bones regarded as metatarsals of iguanodon, or megalosaurus, or, as will appear immediately, with the bones supposed to be metatarsals of ceteosaurus from near Chipping-Norton, or others more satisfactorily determined from Enslow Rocks. It seems to have been by mistake that the locality is marked Enstone; for it bears in Buckland's large handwriting the word 'Blechingdon,' which is the nearest village to Enslow Rocks. The bone has been well figured by Lyell (Manual of Geology, ch. xx.).

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[p] The rib here referred to is not now known to be in the Museum.

The bone, incomplete at both extremities, length, 11·2 inches; breadth at one end, 5·5; at the other 4·75; greatest diameter of shank, 3·3; no medullary cavity; substance small-cellular. It might agree either with a tibia of small dimensions, or a metatarsus of large size; on the latter supposition, probably true, the bone may be regarded as the first in rank of the three larger ones. It would in this case offer some agreement with a corresponding bone from Chipping-Norton.

A series of six bones has come to us from Enslow Rocks, which represents three metatarsals of each foot. The two largest appear to be the first or innermost of the series; the two slenderest are regarded as third. Perhaps there were only three metatarsals, since the specimens we possess exhibit opposite pairs of three, and no more.

The largest are frusta, shewing the proximal ends, 6·0 inches broad, 3·1 deep; the shaft, 3·75 broad, 3·0 deep. These bones, by the narrow slope for apposition on the second metatarsal, differ much from that to be described from Chipping-Norton; they differ equally by the much greater diameter of the shank. The distal extremity is not known.

The next in size and in position, also a pair, as well as can be judged, of opposite sides, have the distal ends partly complete, but the proximal ends wasted. One of these has a length of 14·25 inches (to which something must be added for the incompleteness), the breadth of the distal end 5 inches, its depth 2·5 to 2·75; the shank is 3·3 broad, and 2·25 to 2·5 deep; the articulating surfaces have marks of cartilaginous attachments; the curved surface of the distal end of one of the bones distinguishes the upper and lower sides. The bone is cancellous throughout the interior, the cells being extended in a longitudinal direction.

The third pair of bones is of more slender shape; the length, 14·75 inches, must have exceeded 15·0 when perfect. Breadth near the proximal end, 4·0; near the distal end, 3·5; in the middle of the shaft, 2·5; depth at the proximal end, 2·5; at the distal end, 2·25; in the middle, 2·1.

These bones correspond in general form and place in the foot with one to be described from Chipping-Norton. But they differ much in figure and proportions, and in this agree with the evidence already collected from the first metatarsal, to establish at least specific distinction between the animals of Enslow Rocks and that of Chipping-Norton.

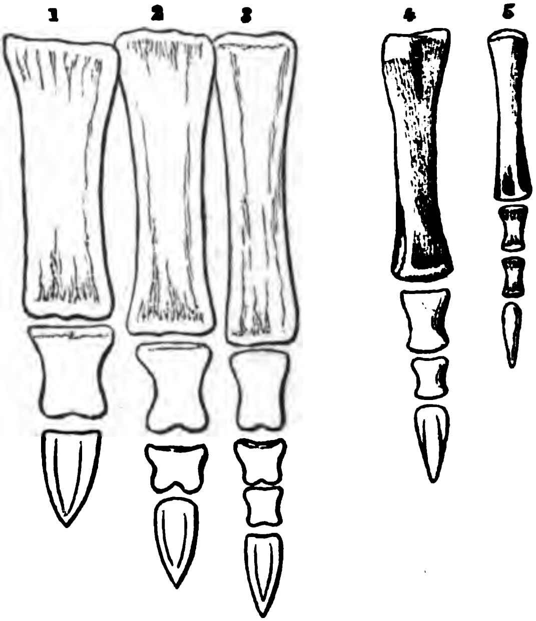

Diagram CXI. Foot-bones of Ceteosaurus, Megalosaurus, and Crocodile. Scale one-tenth.

1, 2, 3. Restorations of the somewhat depressed metatarsals, phalangal, and claw-bones of ceteosaurus. Only the metatarsals were found in proximity to the other bones of the great animal. These bones did not much overlap at the proximal ends, in this respect differing much from megalosaurus and crocodile. 4. Metatarsal of megalosaurus (probably the middle of three), with phalangal bones added, though only the claw-bone is known. 5. Corresponding bones of a crocodile.

Among other specimens from the neighbourhood of Chipping-Norton, presented by Mr. Neate, are four frusta of metatarsals, three of which can be placed so as to give a good idea of half the length of the bones, which appear to be of megalosaurian, not ceteosaurian form. One of them appears to have been the third of the series, possibly on the outside of the left foot, much resembling the megalosaurian bone. It is the proximal end, oblique, expanded horizontally, unequally thick, ridged in the middle of the upper surface, thence sloping inward, concave beneath. Breadth, 5·5 inches; depth, as resting on the lower surface, 3·3; the concavity being 0·4. The shank was slender: its breadth, 1·8; its height, 1·6.

The other metatarsal may be in some degree reconstructed from these frusta. It is very much larger, measuring 6 inches in breadth at the proximal end, which is rectangular to the shaft, and 3·5 in depth. It appears to be the middle metatarsal of the left foot, and much resembles megalosaurus. The fragment reaches the middle of the shaft (8 inches), which there is about 2·75 inches broad and 2·25 deep. The surface is concave below the proximal end toward the inner edge.

Metatarsals, without locality marked on them, but certainly from Glympton, or Chapelhouse near Chipping-Norton, appear in five fragments, four of the proximal ends, one of the distal. They are of opposite feet, two of the left, two of the right; the fifth of uncertain place. They do not correspond to the known types of megalosaurian bones, nor do they better agree with any of those which have been described as ceteosaurian from Enslow Rocks or Chapelhouse. They do not appear hollow in the way bones of megalosaurus appear; but have a largely cellular interior cylinder within a firm exterior sheath. If the interior had been decomposed, the bone would have presented the appearances usual in megalosaurus, from which the hollowness of the bones of that animal has been inferred.

Another set of the bones referred to by Professor Owen presents quite different characters—seven in number. On one is a label written, 'Ceteosaurus, metatarsal and phalangal bones of hind foot —nine bones.' Probably the two phalangal bones presently to be noticed make up the nine.

Of these seven fragments of bones, two of the right foot, a distal and a proximal part, belong apparently to that digit marked II. by Owen in his account of iguanodon; another of the same side, nearly complete, to his No. III.; a fourth, proximal, to the same part of the foot, but on the opposite side. Two are not to be determined. The last to be mentioned is peculiar in figure, and, though of nearly equal size to those mentioned above, appears to agree with no metatarsal or metacarpal bone, but rather to be a first phalangal of extraordinary magnitude. Length, 7.25 inches; breadth of the proximal spheroidal head, 4·0; its depth, 4·75; breadth of the distal end with double condyle, 4·9; its depth, 2·70. (See fig. 1 *a*, Diagram CXII.)

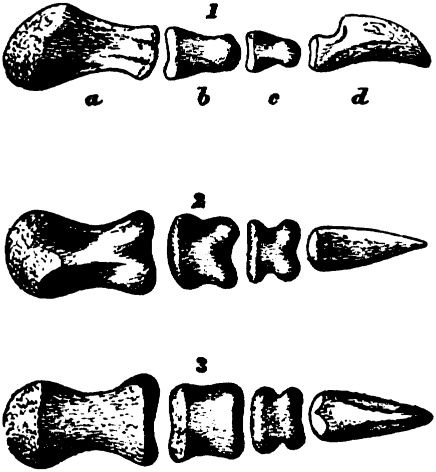

Diagram CXII. **Foot-bones of Ceteosaurus (?), from Chapelhouse, near Chipping-Norton. One-tenth of the natural size.**

1. Sideways. 2. From below. 3. From above.

Combined with the other bones, it seems to constitute a short, bulky, stiff support for a heavy terrestrial quadruped—quite unfitted for aquatic life. There is, however, no certainty that it belongs to the ceteosaurus of Enslow Rocks, or even to that genus.

Phalangal bones are uncommon in the lower oolitic rocks round Oxford. Megalosaurus gives us a claw-bone, but no other of the series; one small toe-bone in the Oxford Museum, from Stonesfield, probably belongs to teleosaurus, and we have two phalangal and one ungual bone of ceteosaurus. In the Oxford and Kimmeridge clays indeed the bones of the marine reptiles are common enough.

The following are the dimensions of the phalangal and ungual bones, the former being much depressed, the latter compressed :—

Fig. 1 *b*, Diagram CXII., from Enslow Bridge. Length, 3·20 inches; breadth of proximal face, 4·15; depth, 2·75.

Fig. 1 *c*, Diagram CXII., from Chapelhouse. Length, 3·00 inches; breadth of proximal face, 3·55; depth, 1·30.

Fig. 1 *d*, Diagram CXII., ungual bone from Chapelhouse. Length, 5·70 inches; breadth of proximal face, 2·6; depth, if complete, 3·00.

A remarkable bone in the Oxford Museum, probably from Chapelhouse, with what appears to be a double articulation-groove, has been conjectured to be the proximal end of an ungual phalanx, but the resemblance is slight.

These are all the bones of ceteosaurus, known to me by personal observation, which have been found in the Bath oolite series. There was, however, one other discovery, and that an early one, near Blisworth, already referred to, which yielded Professor Owen a number of specimens, which are thus summarized in his Memoir to the Geological Society[q]:—

'In the railway cuttings near Blisworth there were found scattered over an area of 12 feet by 8 feet:—

'1. A bone resembling the episternal of an ichthyosaurus, the length or antero-posterior extent of the preserved portion of the median plate being 1½ foot, and the breadth of the posterior fractured end 5 inches, from which it gradually expands to the root of the side branches, where its breadth is 1 foot. From its obtuse termination to the end of the longest branch is 2½ feet, and from this end to that of the opposite branch, 4½ feet.

'2. The remains of a coracoid and scapular apparatus of equally gigantic proportions.

'3. A fragment, considered to be the shaft of a humerus, 1 foot 9 inches in length, 6 inches in diameter across the middle, and 8 inches across the widest end.

'4. A portion of the opposite humerus.

'5. Another fragment, believed to be a part of a radius or ulna, about a yard in length, 6 inches across the proximal end, and 5 inches across the middle of the shaft.

'6. A slightly-curved portion of a rib, a yard long, and from 1½ to 2 inches thick.

'7. Five caudal vertebræ, agreeing in dimensions with the vertebræ of Chipping-Norton.'

I have not been successful in attempts to discover what has happened to this valuable treasure-trove. The bones evidently belonged to the same kind of animal, and might, if re-discovered, help to complete the history of the limbs. Perhaps, if the remains had been treated with the respect shewn to the buried lizard of Enslow Bridge, we might have had from Northamptonshire as large a series of bones, and among them some parts of the head which are still unknown.

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[q] On Ceteosaurus in the Oolitic formations. 1841, p. 60.

While this sheet is passing through the press, I learn that in the National Museum of Geology, in Jermyn Street, some large vertebræ of ceteosaurus are preserved, which were derived from the Great oolite of Essendine, near Grantham.

And another series of caudal vertebræ, one of which almost exactly matches the large specimen represented in Diagrams XCII., XCIII., XCIV., has been found at Chipping-Norton. In the same situation was a fine, though broken, tooth of megalosaurus, crenated on the posterior edge. These are now in the Oxford Museum.

Before passing entirely from the consideration of the animal which has occupied us so long, a few words appear necessary in regard to the names which have been assigned to the two species which appear to be indicated by characteristic differences, especially in the caudal vertebræ and in the metatarsal bones. In the Oxford Museum the first discovered femur was labelled Ceteosaurus giganteus, a name which the larger examples since found may perhaps fully justify. But it will be seen in a future page that the claim is disputable on behalf of some very large vertebræ in the Portland rock of Thame.

Professor Owen, from considerations of the vertebræ known to him, which appeared to be shorter than some named C. longus, and longer than some named C. brevis, gave the name of C. medius (Reports of the Brit. Assoc. 1841).

The application of these names is doubtful only in the case of the Oxford fossils, in which the length of the vertebræ varies considerably in the same animal. In his Memoir on Ceteosaurus (Pal. Soc. 1857), the same author calls the Oxford femur C. longus —a well-deserved epithet—but the vertebræ which belong to this species are not longer than those which previously received the title of medius. To remove ambiguity, then, I propose for the species found in the immediate vicinity of Oxford and elsewhere, the only one for which sufficient materials are collected to serve for determining its characters, the title of Oxoniensis; and as a convenient, if temporary, device, to call the animal with longer caudal vertebræ Glymptonensis, from the name of the place which has yielded the most characteristic series of these bones. This may possibly be equivalent to C. longus, though of earlier date.

The vertebral column of ceteosaurus of which the characters have now been traced offers subjects for grave reflection in reference to the affinities of deinosaurian and crocodilian reptiles. A lizard of such vast proportions would seem to claim easy admission to the deinosaurians, and to take its place naturally with megalosaurus or iguanodon, if not with both those its great contemporaries. But its fore-limbs are more crocodilian, its pelvic girdle more lacertian, while its vertebral system is of a peculiar type, anomalous even in the club-headed neural spine, and singular in the change from opisthocœlian through amphicœlian to what occasionally approaches to procœlian structure.

These vertebræ vary in length in some regular order; increasing in the dorsal series from the forward to the backward bones; greatly diminished, probably in the later lumbar, certainly in the broad first caudals, after which they are again lengthened to about the middle of the tail, and then suffer gradual abbreviation. A downward curvature in some instances appears in the two or three of the last caudals.

The avian affinity so conspicuous in megalosaurus is absent here; in the shortness of the tibiæ some analogy appears to hylæosaurus and scelidosaurus; in the convexo-concave anterior dorsals it agrees with streptospondylus; the limbs are on the whole more crocodilian, except that the hind-foot may have been tridactyle; the pectoral and pelvic arches more Varanian.

Was the dermal surface of this animal loricate, or protected by scuta like those of the crocodile; or squamate, as in many reptiles; or approximately smooth, as in the enaliosaurians? Not loricate, if we may trust the negative evidence obtained at every place yet found to yield bones of ceteosaurus, the same places often yielding scuta of teleosaurus, or steneosaurus. Was the ridge of the back or the tail carinated or crested, as in the monitors and iguanians, with dermal spines or vertical scales? No answer can be given; analogy indeed may be appealed to in favour of this view, which is in harmony with what has been observed in the deinosaurian races which were contemporary with ceteosaurus, or stand to it, though obscurely, in the relation of precursors or successors.

To speculate on the habits of life of the huge creature we have been considering in fragments, may seem a hopeless waste of time, in the absence of almost all trace of a head, and in total ignorance of the special organs of sense and apparatus for obtaining food. Yet some general inferences appear to be justified, and to be worthy of attention. First, in regard to the size of a full-grown animal we have some ground for a reasonable opinion :—

When the great femur came to the Museum accompanied by other bones, its obvious analogy to the corresponding bone in the crocodile suggested and seemed to justify a simple mode of calculation of the size of the animal which had possessed and employed it.

An adult crocodile, 9 feet long, has a femur less than 9 inches long; if like proportions hold, the ceteosaur, which had a femur of 64 inches, must have had a body at least 64 feet long.

Later disinterments made us acquainted with tibia, humerus, and scapula; and if the computation were made for these also, we should have the length of the body as under :—

Twelve or fourteen times the femur	=	64 to 74 feet
Twenty times the tibia	=	63 „
Twenty-four times the scapula	=	100 „
Fifteen or sixteen times the humerus	=	64 „

No small analogy is observed between the deinosaurian reptiles and the living monitors. If we employ the same method, and take the proportions in the same way, the length of the ceteosaur would appear to have been 100 feet.

There are reasons for not being satisfied with these results. The length of limb-bones as compared to the body is too variable to be trusted beyond the limits of a natural family having similar habits of life, and we cannot assume this to be the case on comparing the fossil and recent tribes in question.

The same difficulty occurred in respect of iguanodon and megalosaurus, and it was met by Professor Owen in the same manner, viz. by taking for standard of comparison the vertebral column.

Thus in crocodile, we have usually 7 cervical, 12 dorsal, 5 lumbar, 2 sacral, and 34 to 42 caudal vertebræ. If ceteosaurus were in this respect like crocodile, its length will be thus estimated, allowing for cartilage :—

Seven cervical at 5·0 inches	= 3 feet.
Nineteen dorsal, lumbar, and sacral, at 7·5	= 12 "
Forty-two caudal, at 5·5	= 20 "
Head	= 7 "
Total	42 feet.

If, instead of the crocodile, we take for comparison a monitor or iguana, in which the vertebræ are more numerous, we may assign 60 or 70 feet for the whole length; and combining the two results, with a preference for the first, we shall allow for a full-sized fossil animal the length of 50 feet, and so justify its name of the 'whale lizard.' Probably, when 'standing at ease,' not less than ten feet in height, and of a bulk in proportion, this creature was unmatched in magnitude and physical strength by any of the largest inhabitants of the mesozoic land or sea.

Did it live in the sea, in fresh waters, or on the land? This question cannot be answered, as in the case of ichthyosaurus, by appeal to the accompanying organic remains; for some of the bones lie in marine deposits, others in situations marked by estuarine conditions, and, out of the Oxfordshire district, in Sussex, in fluviatile accumulations.

Was it fitted to live exclusively in water? Such an idea was at one time entertained in consequence of the biconcave character of the caudal vertebræ, and it is often suggested by the mere magnitude of the creature, which would seem to have an easier life while floating in water, than when painfully lifting its huge bulk and moving with slow steps along the ground. But neither of these arguments is valid.

The ancient earth was trodden by larger quadrupeds than our elephant; and the biconcave character of vertebræ, which is not uniform along the column in ceteosaurus, is perhaps as much a character of a geological period as of a mechanical function of life.

Good evidence of continual life in water is yielded in the case of ichthyosaurs, and other enaliosaurs, by the articulating surfaces of their limb-bones; for these, all of them to the last phalanx, have that slight and indefinite adjustment of the bones, with much intervening cartilage, which fits the leg to be both a flexible and forcible instrument of natation, much superior to the ordinary oar-blade of the boatman.

On the contrary, in ceteosaur as well as in megalosaur and iguanodon, all the articulations are definite, and made so as to correspond to determinate movements in particular directions, and these are such as to be suited for walking. In particular, the femur, by its head projecting freely from the acetabulum, seems to claim a movement of free stepping more parallel to the line of the body, and more approaching to the vertical than the sprawling gait of the crocodile. The large claws concur in this indication of terrestrial habits.

But on the other hand, these characters are not contrary to the belief that the animal may have been amphibious; and the great vertical height of the anterior part of the tail (see Diagram LXXXIX.) seems to support this explanation, but it does not go further. For the later caudal vertebræ, instead of being much compressed, as in teleosaurus, are nearly circular in the cross section, and are interlocked by posterior zygapophyses, extended over half, or the whole length of a vertebra.

We have, therefore, a marsh-loving or river-side animal, dwelling amidst filicine, cycadaceous, and coniferous shrubs and trees full of insects and small mammalia. What was its usual diet?

If ex ungue leonem, surely ex dente cibum. We have indeed but one tooth, and that small and incomplete. It resembles more the tooth of iguanodon than that of any other reptile; for this reason it seems probable that the animal was nourished by similar vegetable food which abounded in the vicinity, and was not obliged to contend with megalosaurus for a scanty supply of more stimulating diet.

CHAPTER XII.

THE OXFORD OOLITE PERIOD.

In a complete form this series of argillaceous, arenaceous, and calcareous strata includes the following parts:—

Kimmeridge Clay above.

Upper calcareous grit	In Yorkshire and Dorsetshire.
Coralline oolite	Oxfordshire, &c.
Lower calcareous grit	Heddington.
Upper Oxford clay	St. Clement's.
Middle Oxford clay	Oxford.
Kelloway rock	Wilts.
Lower Oxford clay	North of Oxford.

Cornbrash below.

Of these, the upper calcareous grit is hardly traceable near Oxford, and is best seen near Malton; and the Kelloway rock is most fully explored at Hackness, near Scarborough, but scarcely known in the drainage of the Thames. The Oxford clay in the vicinity of St. Ives has been found to contain distinct stone beds above the Kelloway band, but they do not openly occur in the country round Oxford, though some evidence of such was found in the deep boring at Wytham.

OXFORD CLAY AND KELLOWAY ROCK.

Except in wells, brick-yards, and road-cuttings, the thick argillaceous deposit which is the base of the Oxonian series is rarely seen to advantage in the interior of England. On the coasts of

Dorset and Yorkshire, at Weymouth and Scarborough, it is otherwise. One railway cutting, near Chippenham, disclosed a variety of ammonites and belemnites and other cephalopods in unusual completeness; and we have a not inconsiderable series of crustacea, shells, fishes, and reptiles from the vicinity of Oxford. The deposit fills a broad, low, continuous tract from near Malmesbury, by Cricklade, along the Upper Thames to Oxford, and thence occupies a wide and depressed area by Ottmoor, and the north side of Brill, to Winslow, Bedford, and Huntingdon. Though it appears but little varied in composition as we see it near the surface, a deep boring at Wytham disclosed a considerable diversity. The boring, as reported by the workmen, reached the depth of 633 feet, and passed through fifty-nine layers which appeared to differ in hardness and consistency.

The following is a summary of the results obtained in this remarkable boring, copied from a section presented to the Oxford Museum, in 1849, by the Earl of Abingdon. The terms employed by the workmen are used in the coal-fields of Staffordshire for strata somewhat analogous:—

			Total depth.	
	ft.	in.	ft.	in.
1. Loamy ground	12	0	12	0
2. Quicksand and water	3	0	15	0
3. Blue clunch	68	6	83	6
4. Light clunch	1	6	85	0
5. Blue clunch	28	6	113	6
6. Clunch bines	4	6	118	0
7. Blue clunch	29	0	147	0
8. Clunch bines	2	0	149	0
9. Blue clunch	28	0	177	0
10. Brown clunch	3	0	180	0
11. Mingled ground	11	6	191	0
12. Strong grey rock	1	0	192	6
13. Grey clunch	2	0	194	6
14. Brown clunch	1	6	196	0
15. Mingled ground	17	0	213	0
16. Blue clunch bines	6	0	219	0
17. Mingled ground	4	0	223	0
18. Brown clunch	17	6	240	6
19. Mingled ground	9	6	250	0
20. Blue clunch	5	0	255	0
21. Dark blue rock	3	6	258	6
22. Dark parting clunch	0	6	259	0
23. Dark blue rock	2	6	261	6

			Total depth.	
	ft.	in.	ft.	in.
24. Dark clunch	11	6	273	0
25. Strong blue rock	10	6	283	6
26. Dark parting clunch	1	0	284	6
27. Strong blue rock	5	6	290	0
28. Strong parting clunch	0	6	290	6
29. Blue rock	1	6	292	0
30. Clunch and clunch bines	6	0	298	0
31. Grey rock	18	0	316	0
32. Dark parting clunch	0	6	316	6
33. Light rock	30	3	346	9
34. Light parting clunch bines	0	9	347	6
35. Light rock	5	0	352	6
36. Very dark parting	2	0	354	6
37. Grey rock	1	4	355	10
38. Dark parting	0	8	356	6
39. Clunch bines	7	6	364	0
40. Grey rock	3	0	367	0
41. Dark parting	1	6	368	6
42. Grey rock	2	6	371	0
43. Blue bines	2	0	373	0
44. Mingled ground	3	0	376	0
45. Blue rock	9	0	385	0
46. Dark ground	1	6	386	6
47. Mingled ground	7	6	394	0
48. Light rock	16	6	410	6
49. Black bat	2	0	412	6
50. Rock	35	6	448	0
51. Mingled ground	11	6	459	6
52 to 55. Mingled ground	3	0	462	6
56. Ironstone	0	4	462	10
57, 58. Clunch mixed with ironstone	132	0	594	10
59. Dark clunch	2	0	596	10

'The boring was carried to the depth of 211 yards, the strata the same as that at 596 feet.'—C. Webb.

The operation was conducted by E. Bagnall, Mine-Agent, Baskerville House, Birmingham, and was finished before May 1829.

Another excavation at St. Clement's, Oxford, said to be 265 feet in this clay, and 135 feet in 'rock' below it, yielded vertebræ of ichthyosaurus; and a third, at the Aylesbury Asylum, showed zones of Gryphæa dilatata and other characteristic fossils. We have no example here of the fine septaria of Dorset, nor more than the usual abundance of pyrites and selenite, both of which occur in connection with bones and shells. The fossils, if not very numerous, are interesting and remarkable, especially ammonites, as may be seen in the Catalogue, which includes those gathered from all parts of the series within the Oxonian district. This clay comes into juxtaposition with the Kimmeridge clay in the country north-east of Oxford. Its extreme thickness, as proved by the boring at Wytham, exceeds 200 yards. The middle part, north of Oxford, yields Ammonites Duncani; the upper part, about St. Clement's, supplies Ammonites vertebralis; while between the two, in wells at Oxford, we have Ammonites Lamberti. The Kelloway rock is not really traceable in this quarter, but a band of septaria occurs, fifty feet above the cornbrash, near Kirtlington Station, at about the place of this rock, and containing some ammonites of the epoch.

CALCAREOUS GRIT.

Sand partly consolidated into sandstone is the basis of this deposit through all the low escarpment of the tract which looks northwards on the upper vale of Thames. It is rarely exposed except in road-cuttings, and at the base of the 'coral rag,' where that is quarried for the roads and walls. This occurs on the road to Shotover, at Cowley and Bullingdon, and in the country near Besselsleigh and Marcham. It is in these cases usually a fine sand, with occasional shells; the more solid parts lower down are rarely found to be of use even for the rudest rural purposes. It is indeed actually used on the roads at Studley, north-east of Oxford, beyond which it can hardly be traced at all, till the series of these rocks opens and expands in Yorkshire. Near Oxford its total thickness is about 60 or 70 feet. The sand is sometimes so loose as to be 'quick,' and choke the wells which in many places are sunk to it through the superincumbent rock and clay. This happened at Even-Swindon, where a deep well through Kimmeridge clay reached and penetrated the coralline oolite. Then burst up a great stream of water, followed by sand in such abundance as to fill the well to a considerable height. Near Abingdon, as about Marcham, it is thin but fossiliferous, especially yielding many fine specimens of Ammonites catena, and a solitary example of Hemipedina Marchamensis. At Studley, Ammonites vertebralis, Pholadomya, Modiola, Pinna, and other shells occur.

In the railway cutting at Kennington this sand, fully exposed, is varied with beds and large nodules of sandstone slightly calcareous, while, for a considerable space towards Littlemore, lie widely-interrupted parts of the next rock above, viz. coralline oolite.[*] The oolite lies in separated patches on the same plane, which were probably connected; the intervals between them are occupied by sand which may be supposed to have been left after the decomposition of the oolite. The upper parts of the oolite are absent for a large tract hereabout; and it may be supposed that the large waste of them was caused by long exposure to atmospheric agency in very ancient times (pre-glacial or earlier). This process of surface waste has affected a great part of the area of coralline oolite in Oxfordshire, Berkshire, and Wilts, and seems to explain the patchy and irregular distribution often observable in this rock; though, as far as relates to the purely oolitic and not shelly part of the rock, the original circumstances of deposit must be taken into account.

CORALLINE OOLITE.

A part of this rock is formed of considerable masses of coral mixed with many shells—the 'Coral rag' of Smith; other parts contain large spherical or egg-shaped grains—the 'Pisolite' of the same author; extreme total thickness 40 or 50 feet. Coral beds of much continuity can hardly be quoted, yet the mixed mass of coral and shells may justly be compared with some parts of the Bermuda reefs, which are formed under the influence of currents in extended sheets, while others grow up in vertical accretion. The upper surface of the more oolitic part of the rock under the Kimmeridge clay at Heddington is water-worn. The quarries at this place have been used for extracting stone to build some colleges in Oxford. It is found to be far from durable; the best example being in Wadham College, which had exceptional means of selecting material from the best quarries. No other locality has furnished much building-stone from this oolite, though at Wotton-Basset it is largely excavated for walling and lime-burning. The lower and more shelly parts of the rock are usually found near Oxford much disintegrated by atmospheric action and rain currents, whereby the corals and shells are separated and form a loose congeries of remarkable aspect. The lowest beds are not thus broken up, but remain solid and shelly, and make a sort of cap to the subjacent

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sands. Shelly beds of similar character occur in some places inclosed in these sands; and thus the passage is easy from the oolite to the sands.

Fossils are numerous in this rock, both on the Heddington side and the Cumnor side of Oxford; and they have on the whole very much of the same character from the vicinity of Calne and Steeple-Aston, by Wotton-Basset, Highworth, and Faringdon, to Fifield, Besselsleigh, Cumnor, Heddington, and Stanton St. John, where the deposit seems to terminate. Some slight continuation (a bed of oyster shells) has, however, been traced by Mr. Polwhele across the space between Stanton St. John and Studley.

FOSSILS OF THE OXFORD OOLITE SERIES FROM LOCALITIES NEAR OXFORD.

The Catalogue of the Museum of Practical Geology, 1865, a List drawn up by Mr. Whiteaves for the Coralline oolite fossils, in 1861, and Dr. Wright's Monograph of Echinodermata, have been consulted with advantage. The quarries have been examined often enough to furnish a fair, though probably not full, list.

Abbreviations used:—O. C. for Oxford Clay; C. G. for Calcareous Grit; C. O. for Coralline Oolite; U. Upper part; M. Middle part; L. Lower part.

PLANTS. Fragments of coniferous wood occur in all these strata.
Carpolithus plenus. n. s. *Phil.* C. O. Marcham.

AMORPHOZOA. A few specimens of spongiadæ. C. O. Heddington, Bullingdon.

FORAMINIFERA frequent in the central parts of the oviform grains.

ACTINOZOA.
Anabacia orbulites. *Lam.* O. C. St. Clement's.
Cladophyllia Conybeari. *Edw.* C. O. Cumnor.
Isastræa explanata. *Goldf.* C. O. Cumnor, Heddington.
„ Greenovii. *Edw.* C. O. Bullingdon.
Montlivaltia dispar. *Phil.* C. O. Heddington, Cumnor.
Rhabdophyllia Phillipsii. *Edw.* C. O. Cumnor.
Thamnastræa micrastron. *Phil.* C. O. Cumnor.
Thecosmilia annularis. *Flem.* C. O. Cumnor.

These corals, for the most part unaccompanied by spongiadæ, are almost confined to the oolitic beds, in which they are so mixed with shells and so disposed as to suggest the idea of limited shallow banks on which sea life found a suitable place. Thus viewed, the coralline oolite and calcareous grits must have been produced in long fringes and detached banks during a pause of the watery action which continued during all the age of the Oxonian clay, and again resumed its sway for an equal 'Kimmeridgian' period after the coralline deposits ceased. In neither of these clays is coral of any sort other than a very rare occurrence, and the only species yet recognized belongs to the small genus Anabacia.

ECHINODERMATA.
Echinoidea.
Acrosalenia spinosa. *Ag.* O. C. St. Clement's.
Cidaris florigemma. *Phil.* C. G., C. O. Bullingdon, Heddington, Cumnor.
„ insperata. n. s. *Phil.* O. C. St. Clement's.
„ Smithii. *Wr.* C. G., C. O. Heddington.
Clypeus subulatus. *Y.* and *B.* C. O. Heddington.
Echinobrissus dimidiatus. *Phil.* C. G., C. O. Heddington, Cowley, &c.
Hemicidaris intermedia. *Flem.* C. O. Heddington.
Hemipedina Marchamensis. *Wr.* C. G. Marcham.
Pseudodiadema versipora. *Phil.* C. O. Heddington.
Pygaster umbrella. *Wr.* C. O. Heddington.
Pygurus Blumenbachii. *Koch* and *Dunk.* C. O. Bullingdon.
„ costatus. *Wright.* C. O. Bullingdon.
„ pentagonalis. *Phil.* C. O. Heddington.
Asteroidea.
Astropecten rectus. C. G. Cowley.
Crinoidea.
Apiocrinus. . . . C. O. Heddington.
Extracrinus. O. C. St. Clement's.
Millericrinus echinatus. *Schl.* C. O. Heddington.

This very small series of the Echinodermata has not been obtained without much research in the strata near Oxford. The rarity of Hemicidaris, Pseudodiadema, and Pygurus makes a great difference to collectors at Oxford and Calne.

Of these fossils only a few rare traces occur in the clay beds round Oxford, nor are such found in plenty or variety in other parts of this argillaceous series. It is rather in the shelly (middle) series than in the purely (upper) oolitic parts of the coralline rock that they are to be looked for.

FOSSILS OF THE OXFORD OOLITE SERIES.

ANNELLIDA.
Serpula runcinata. *Sow.* C. O. Heddington.
„ squamosa. *Phil.* C. O. Cumnor.
„ tricarinata. *Sow.* C. O. Heddington.
Vermicularia ovata. *Sow.* C. O. Heddington.
Vermilia sulcata. *Sow.* C. O. Heddington.

CRUSTACEA.

Glyphea rostrata. *Phil.* C. O. Heddington.

„ Stricklandi. *Bean.* O. C. St. Clement's.

A short-tailed Decapod. O. C. St. Clement's.

POLYZOA.

Diastopora diluviana. O. C. St. Clement's.

The rarity of polyzoa in the Oxford oolites and clays is somewhat remarkable, and appears to be in some way related to the even more remarkable rarity of brachiopoda, on whose shells in the Bath oolites so many of these beautiful objects are found.

BRACHIOPODA.

Discina latissima. *Sow.* O. C. St. Clement's.

„ radiata. *Phil.* C. O. Bullingdon.

Rhynchonella varians. *Dav.* O. C. Summertown. (rare.)

Terebratula buoculenta. *Sow.* C. O. Bullingdon.

„ impressa. *Von Buch.* O. C. Oxford.

„ insignis. *Schül.* C. O. Heddington, Cumnor.

The scarcity of these fossils in the Oxford oolites and clays contrasts strongly with the abundance of them in the parallel older series below. Till lately our collection did not possess a single terebratula from the coralline oolite, and though now two species are in the catalogue, one is founded on a unique valve; and still we have no rhynchonella and no lingula from this rock.

MONOMYARIA.

Avicula expansa. *Phil.* C. O. Heddington.

„ ovalis. *Phil.* C. O.

Gervillia aviculoides. *Sow.* C. O. Heddington, Bullingdon.

Gryphæa dilatata. *Sow.* O. C. St. Clement's, &c. C. O. Heddington.

Lima elliptica. *Whit.* C. O.

„ læviuscula. *Sow.* C. O. Heddington.

„ pectiniformis. *Schl.* C. O.

„ rigida. *Sow.* C. O. Heddington.

„ rudis. *Sow.* C. O. Bullingdon.

„ rustica. *Sow.* C. O. Heddington.

Ostrea gregarea. *Sow.* O. C. u. St. Clement's. C. O. Heddington, &c.

„ solitaria. *Sow.* Bullingdon.

„ spinigera. n. s. C. O. Bullingdon.

Pecten articulatus. *Schl.* C. O. Heddington.

„ fibrosus. *Sow.* O. C. Summertown.

„ lens. *Sow.* C. O. Heddington.

„ similis. *Sow.* C. O. Heddington.

„ vagans. *Sow.* C. O. Cumnor.

„ vimineus. *Sow.* C. O. Heddington, Cumnor.

Pinna lanceolata. *Sow.* C. O.
„ mitis. *Phil.* C. G. Studley.
Placunopsis similis. *Whit.* C. O. Bullingdon.
Trichites Plotii. *Lhwyd.* C. O. Heddington.

In this list of monomyaria the usual oolitic groups appear gathered round avicula, lima, ostrea, and pecten; gryphæa being abundant in the Oxford clay and lying in several extensive floors, but scattered and comparatively rare in the strata above. A small smooth oyster is so abundant in the shelly oolitic layers as almost to constitute beds, but the valves are seldom associated, while, on the other hand, Ostrea gregarea forms in these same beds large coherent masses with united valves.

DIMYARIA.

Arca æmula. *Phil.* C. O. Heddington.
„ subtetragona. *Mor.* O. C.
Astarte extensa. *Phil.* C. O. Heddington.
„ ovata. *Smith.* C. O. Heddington, Bullingdon.
„ rhomboidalis. *Phil.* C. O. Marcham.
Cardium Crawfordii. *Whit.* C. O.
Corbis lævis. *Sow.* C. O. Heddington.
Corbula MacNeillii. *Mor.* O. C.
Cucullæa concinna. *Phil.* O. C.
„ contracta. *Phil.* C. O.
Cypricardia isocardina. *Buv.* C. O.
Cyprina dolabra. *Phil.* C. O.
Goniomya literata. *Sow.* C. O., C. G. Studley.
Isocardia tumida. *Phil.* C. G.
Leda Phillipsii. *Mor.* O. C.
Lithodomus inclusus. *Phil.* C. O. Heddington, Cumnor.
Lucina crassa. *Sow.* C. O.
„ lirata. *Phil.* O. C.
„ polita. *Phil.* C. O. Bullingdon.
Modiola bipartita. *Sow.* C. G. Studley.
„ cuneata. *Sow.* C. G. Studley.
„ pulchra (?). *Phil.* C. O.
Myacites calceiformis. *Phil.*
„ recurvus. *Phil.* O. C. St. Clement's. C. G. Studley.
Nucula elliptica. *Phil.* O. C. St. Clement's, Oxford.
„ nuda. *Phil.* O. C. St. Clement's, Oxford.
Opis corallina. *Lyc.* C. O. Bullingdon.
„ Phillipsii. *Mor.* C. O.
Pholadomya obsoleta. *Phil.* C. G. Studley.
Quenstedtia lævigata. *Phil.* C. O.
Sowerbya Deshaysii. *Buv.* C. O. Bullingdon.
„ triangularis. *Phil.* C. O. Heddington.
Tancredia curtansata. *Phil.* C. O.

Thracia depressa. *Sow.* O. C.
  „ Studeri. *Ag.* C. O. Bullingdon.
Trigonia clavellata. *Sow.* O. C. St. Clement's. C. O. Heddington.
  „ costata. *Park.* O. C. St. Clement's. C. O. Heddington.
  „ triquetra. *Lyc.* C. O. Heddington.

The whole list of dimyarian mollusks is of the ordinary character of the Bath oolites—a return one might think of the descendants of the old sea denizens to the home of their sires. Nor are the children much altered in form through the lapse of time and change of circumstances.

GASTEROPODA.

Actæon retusus. *Phil.* C. O.
Actæonina polygyra. n. s. *Phil.* C. O. Cumnor.
Alaria bispinosa. *Sow.* O. C. St. Clement's.
  „ seminuda. *Heb.* and *Desb.* C. O. Bullingdon.
Bulla elongata. *Phil.* C. O.
Ceritella costata. *Whit.* C. O.
Cerithium muricatum. *Sow.* C. O. Bullingdon, Cumnor.
Chemnitzia Heddingtonensis. *Sow.* C. O. Heddington.
  „ melanioides. *Phil.* C. O.
Cylindrites Luidii. *Whit.* C. O.
Littorina lævissima. *Whit.* C. O.
  „ muricata. *Sow.* C. O. Heddington, Cumnor.
Murex Haccanensis. *Phil.* C. O. Bullingdon.
Natica arguta. *Phil.* C. O. Heddington, Cumnor.
  „ clio. *D'Orb.* C. O.
Nerinæa Goodhallii. *Sow.* C. O.
Nerita brevispiralis. n. s. C. O. Heddington.
  „ minuta. *Sow.* C. O.
Phasianella striata. *Sow.* C. O. Heddington.
Pleurotomaria bicarinata. *Sow.* C. O. Cumnor.
  „ depressa. *Phil.* O. C. Bullingdon.
  „ reticulata. *Sow.* C. O.

The resemblance of this list to the larger and richer catalogue of the Great and Inferior oolite is very great. It is perhaps safe to view it as a 'pauperized' fauna, indicating the approaching extinction of physical conditions which marked the oolitic ages and influenced the life of the period.

CEPHALOPODA.

Ammonites athleta. *Phil.* O. C. Summertown.
  „ biplex. *Sow.* var. O. C. Wolvercot, Summertown.
  „ canaliculatus. *Munst.* O. C. Summertown.
  „ catena. *Sow.* C. G. Marcham.
  „ cordatus. *Sow.* O. C. St. Clement's. C. G. Studley. C. O. Heddington.

Ammonites Duncani. *Sow.* Ō. C. Wolverton.
„ excavatus. *Sow.* C. O. Heddington.
„ gemmatus. *Phil.* O. C. St. Clement's.
„ Gowerianus. *Sow.* O. C. Islip, Summertown.
„ ingens. *Y.* and *P.* C. R. Heddington.
„ Jasoni. O. C. Summertown.
„ Lamberti. O. C. Oxford.
„ Mariæ. *D'Orb.* O. C. Summertown.
„ oculatus. *Phil.* O. C. Summertown.
„ perarmatus. *Sow.* C. G., C. O. Heddington.
„ plicatilis. *Sow.* C. G., C. O. Heddington.
„ Sutherlandiæ. *Sow.* C. O. Well in Oxford.
„ triplex. *Sow.* C. O. Shotover.
„ varicostatus. *Buck.* O. C. Hawnes near Bedford.
„ vertebralis. *Sow.* C. O. Heddington.
Belemnites abbreviatus. *Mill.* C. O. Heddington. O. C. St. Clement's.
„ hastatus. *Blainv.* O. C. St. Clement's.
„ Owenii. O. C. Summertown.
„ porrectus. *Phil.* O. C. St. Clement's.
„ sulcatus. *Mill.* O. C. Summertown, Wolvercot.
„ tornatilis. *Phil.* O. C. St. Clement's.
Nautilus hexagonus. *Sow.* C. G. Marcham.

In this list extensive changes of the general forms of ammonites and belemnites appear in the natural order of successive groups of life. Belemnites, which appear to be rare in the Bath oolites of this district, are here renewed in races of a different general aspect. Many of the ammonites belong to earlier groups though specifically different; but one in particular, the group called 'Ornati,' including A. Duncani, appears and prevails in the Oxford clays, without entering the oolitic shelly beds above, or reappearing in the Kimmeridgian clays. One part of this beautiful group is absent, or very rare—the species called Calloviensis—probably because the Kelloway stone is not here; and for the same reason probably we do not record A. sublævis. But both may perhaps be found hereafter though rarely.

FISHES.

Asteracanthus ornatissimus. *Ag.* C. O. Heddington.
Gyrodus. O. C. St. Clement's.
Hybodus grossiconus. *Ag.* O. C. St. Clement's.
„ obtusus. *Ag.* C. O.
„ polyprion. *Ag.* O. C. St. Clement's.
Ischyodus Egertoni. *Ag.* O. C. St. Clement's.
Lepidotus macrocheirus? *Egert.* O. C. St. Clement's.
Pycnodus Bucklandi. C. O. Wheatley.

Among these few fishes the most remarkable is the Ischyodus Egertoni of Agassiz, of which good jaws have been collected from St. Clement's, in the upper Oxford clay. I have endeavoured to give clear views of the internal and external aspects of these remarkable bones, which are also teeth, and represent in the old world such curious creations as the Diodon of modern seas. See Plate XII. For descriptions I must refer to Agassiz's great work on Fossil Fishes.

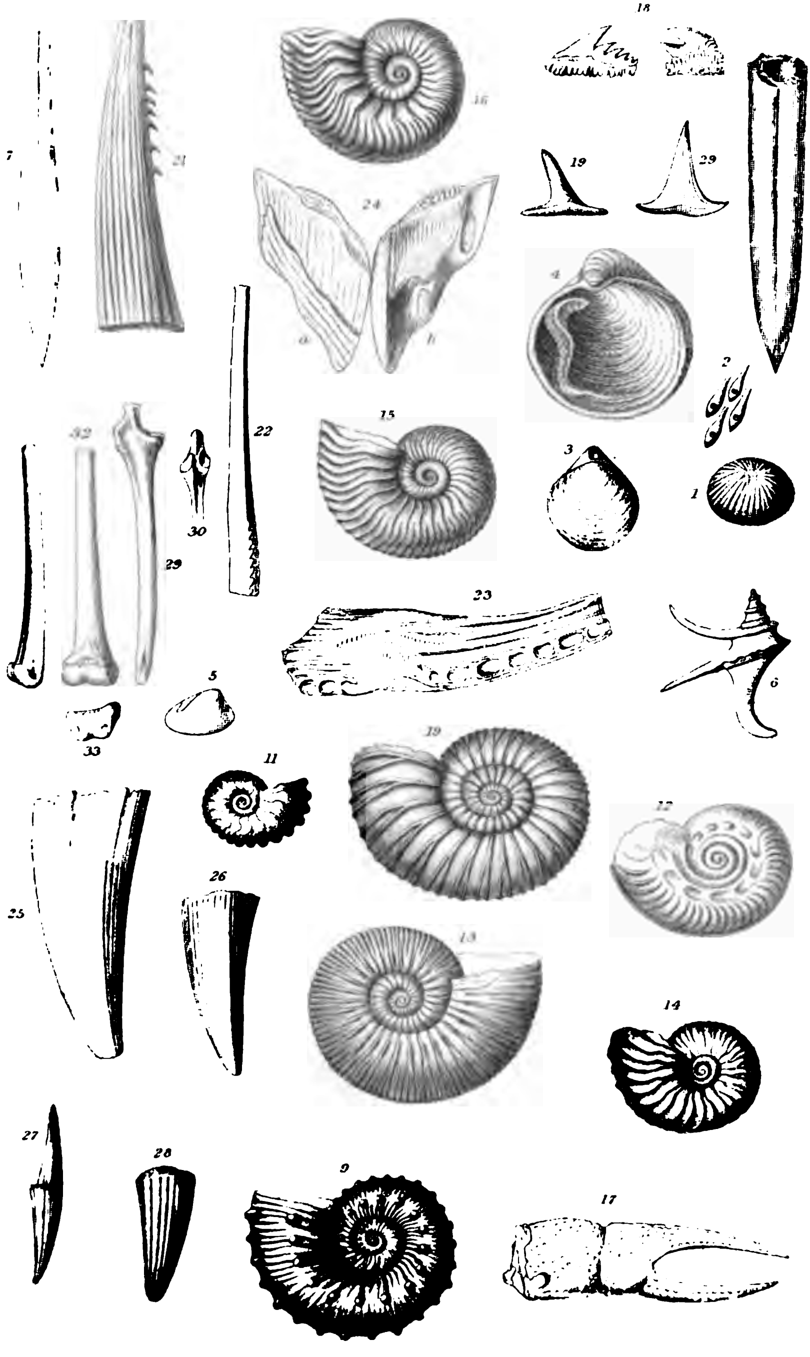
REPTILIA.

Dakosaurus. O. C. St. Clement's.
Ichthyosaurus dilatatus. n. s. *Phil.* O. C. St. Clement's.
,, thyreospondylus. *Owen.* O. C. Buckingham.
Megalosaurus Bucklandi. O. C. Near Oxford. C. O. Littlemore, Dry-Sandford.
Pleiosaurus gamma. *Owen.* O. C. St. Clement's.
,, grandis. *Owen.* O. C. Peterborough.
Plesiosaurus eurymerus. n. s. O. C. Bedford.
,, Oxoniensis. n. s. *Phil.* O. C. Summertown, St. Clement's, &c.
,, plicatus. O. C. Summertown.
,, trochanterius. *Owen.* O. C. Chippenham.
Rhamphorhynchus Bucklandi. O. C. St. Clement's.
Steneosaurus . . . O. C. Long Marston.
Streptospondylus Cuvieri. *Owen.* O. C. Near Oxford. (See p. 319.)

REFERENCE TO PLATE XII., REPRESENTING FOSSILS OF THE OXFORD CLAY.

1. Anabacia orbulites.
2. Diastopora diluviana.
3. Terebratula impressa.
4. Gryphæa dilatata, with attached Serpula tricarinata.
5. Nucula elliptica.
6. Alaria bispinosa.
7. Belemnites hastatus.
8. ,, sulcatus.
9. Ammonites Duncani.
10. ,, biplex ?
11. ,, oculatus.
12. ,, canaliculatus.
13. ,, Gowerianus. Jun.
14. ,, Mariæ.
15. ,, Lamberti.
16. ,, vertebralis.
17. Glyphea Stricklandi.
18. Hybodus polyprion.
19, 20. Hybodus grossiconus.
21. Hybodus grossiconus. Spine.
22. Leptacanthus. Spine.
23. Jaw of Gyrodus ?
24. Ischyodus Egertoni, seen on the outer face *a*, inner face *b*.
25. Tooth of Pleiosaurus.
26. Tooth of Pleiosaurus.
27. Tooth of Saurian.
28. Tooth of Saurian.
29. First phalanx, wing finger of Rhamphorhynchus.
30. Proximal articular face of the same phalanx.
31. Femur of Rhamphorhynchus. Sideways.
32. The same seen in front.
33. Distal articular face of the same.

OXFORD CLAY.



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ICHTHYOSAURUS DILATATUS. *Phil.*

Three cervical and ten dorsal vertebræ of this group of saurians were obtained at a considerable depth in the deep well sunk in Oxford clay at St. Clement's. They are somewhat remarkable for neatness of outline and a general smoothness of surface. In the articulating face of the anterior cervical vertebræ the height rather exceeds the breadth, and the figure is somewhat pentagonal, and angular below; in the dorsal series the breadth is greater, and the outline below is circular.

Dimensions. Cervical vertebræ: length, 1·0 inch; breadth, 2·0; height to canal, 2·2. Dorsal vertebræ: length, 1·3; breadth, 2·9; height, 2·8.

A valuable series of vertebræ of this species, beginning with the anchylosed atlas and axis, and extending without interruption to the 25th, has been obtained from the upper part of the Oxford clay in Cowley Field. The vertebræ of St. Clement's go to the 40th.

This is perhaps not essentially different from the species, plentiful in the Kimmeridge clay, to which Owen attached the name of I. trigonus. That species, whose anterior cervical vertebræ are much higher than broad, will be more fully described hereafter.

ICHTHYOSAURUS THYREOSPONDYLUS[a]. *Owen.*

One vertebra, whose place in the column was about the eighth from the head, obtained from the Oxford clay at Buckingham, belongs apparently to the well-marked species named above; which is more plentiful in the Kimmeridge clay of Shotover, under which head it will be more fully described. Length, 1·0 inch; breadth, 2·25; height to canal, 2·3: very deeply concave on the articulating faces, with a few radiating plications. Neural canal flat and broad on the base.

PLESIOSAURUS OXONIENSIS. n. s. *Phil.*

The deep clay which spreads round Oxford has yielded in its frequent brick-yards several interesting remains of a plesiosaurus, which manifests specific characters in such parts as have been collected. It may be regarded as the analogue of Plesiosaurus brachyspondylus, to be noticed hereafter as a fossil of Kimmeridge clay. Of the head almost nothing intelligible; indeed of the whole of the anterior part of the body very little, except vertebræ and a few ribs. The vertebral column is nearly complete, and of the posterior part, and especially of the pelvic girdle and paddle bones, the examples are in plenty.

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[a] No locality is given for this species by Professor Owen, whose described specimen, in the Bristol Museum, was probably from Weymouth, where it is not uncommon.

Of cervical vertebræ, one series of six has come to us from the clay-pits of Long-Marston. These are from a very forward part of the neck near the head, and shew in a striking manner the rapid augmentation in size of the anterior cervicals which is observed in several species of the genus found near Oxford. They are biconcave, with a narrow somewhat tumid interforaminal space.

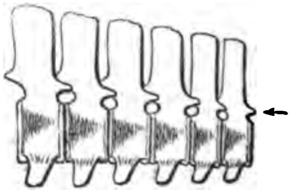

Diagram CXIII. Six Cervical Vertebræ of Plesiosaurus Oxoniensis. Scale, one-fifth of nature.

The largest of these vertebræ measures on the articular face—in height, 1·3 inch; in breadth, 1·6; and the length is 1·1: the smallest in height, 0·9; in breadth, 1·2; and is 0·85 long.

Vertebræ of the dorsal series occur rather frequently, and, except for fractures which would not occur if the workmen were at all careful, they might be generally preserved quite perfect.

These vertebræ are somewhat remarkable for the almost circular outline of the articular faces, only broken at the upper margin by the neural canal, for the sharply-defined border of these faces, and a general smoothness and neatness of surface. The zygapophyses are very clearly marked; the anterior pair deeply spoon-shaped; the posterior pair formed of plates inclined toward each other 45°, and rounded beneath to fit into the anterior grooves. The articulating faces are equally concave, the depth being about one-tenth of the diameter. The foramina are lateral. Transverse diameter of the largest, 2·75 inches; height, 2·5; length, 2·1. They may be regarded as middle dorsals.

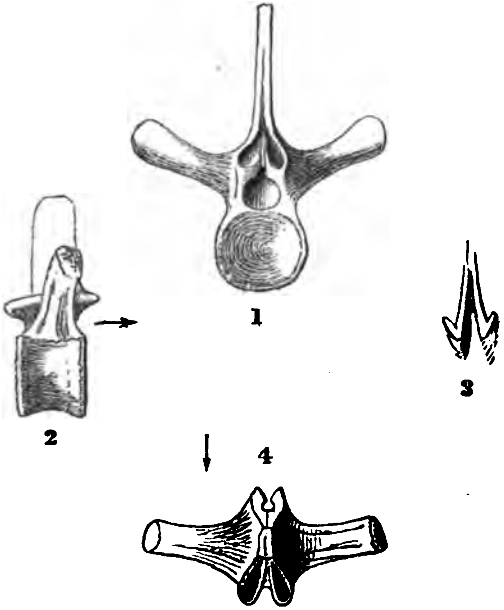

Diagram CXIV. Dorsal Vertebræ of Plesiosaurus Oxoniensis. Scale, one-fifth of nature.

1. Seen from the front. 2. Side view. 3. Posterior zygapophysis. 4. Seen from above.

Ribs.—Portions have been found. One of a very great size must have belonged to another species of animal not otherwise indicated. They are of the usual form of middle dorsal ribs, with hardly a mark of that division across the head which occurs in the cervical ribs. The substance is largely cellular in the middle, more compact toward the sides.

Caudal vertebræ are exemplified by a series of eight, which appear to be consecutive, and to indicate a rapid contraction of the size of the tail, which must have been shorter than is usual in the genus. Their lateral processes extend, from point to point, to about twice the breadth of the vertebra. The vertebræ nearest the end have cicatrices on both the lower edges, those further forward on the posterior edge only.

The largest has a length of 1·45 inch, a breadth of 2·1, and height (to the canal) 1·5; in the smallest the measures are, length, 0·85; breadth, 1·2; height to the canal, 0·90.

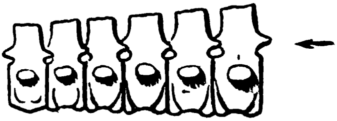

Diagram CXV. Six Caudal Vertebræ of Plesiosaurus Oxoniensis. Scale, one-fifth of nature. The articular surfaces biconcave, and rather pitted in the middle.

Pelvic girdle.—The materials for describing this part of the skeleton are complete in respect of the pubic and ischial bones, which, though never found together in the way represented in Diagram CXVI., were probably so arranged in the living animal.

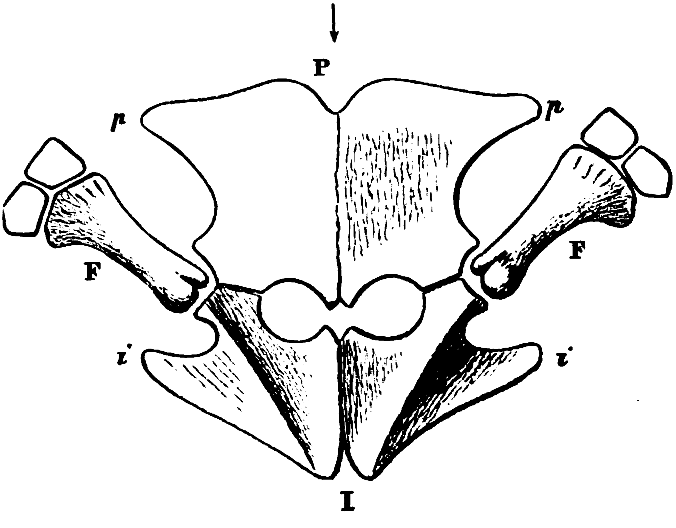

Diagram CXVI. Pelvic Girdle of Plesiosaurus Oxoniensis. Scale, one-tenth of nature.

P. Pubis. I. Ischium. F. Femur.

The shapes of both these bones are somewhat peculiar, and it is only after long and frequent consideration and comparison with remains of other plesiosaurians, and skeletons of recent turtles, that the arrangement in the woodcut was adopted. The anterior portion of the pubis, incomplete in the middle parts, is supplied by general analogies: nothing else is doubtful. One of the ischial bones is so nearly complete as to fully justify the outlines of both, except at the posterior edge.

So few complete examples of these bones clearly separated from the matrix have been carefully represented, that it seems worth while to call attention to some of the points which mark the Oxford plesiosaurus with a peculiar aspect.

The pubis, preserving a large area in proportion to the ischium, and meeting it so as to leave between the bones the doubly-cycloidal interval nearly as usual, runs out into wings on the anterior border, and from these deep curves return to the femoral joint. The bones, generally thin, meet in a long, straight symphysis, with surfaces very deep in the posterior part, but shallow toward the front. There is some intumescence in the posterior part, not deserving the title of carination, on the outer or lower side.

The ischium is remarkable for the strong, sharp keel or angular band, which runs from the acetabulum to near the posterior edge, and for the lateral wings, which advance far forward, and are separated from the acetabulum by a deep, sharp, inward curve. The bone is vaulted below, and the symphysis is deepest anteriorly.

Dimensions: *P* to *I*, along the middle of the bones, 21 inches; *pp*. across the pubis, 21; *ii*. across the ischia, 21; breadth between the acetabula, 13.

These dimensions are the average of two sets of bones belonging to two animals.

As yet no ilium has been discovered.

The first bone of the hind-leg in the largest example is 11·9 inches long; the extreme breadth at the distal end being 7 inches.

The proximal extremity is 3·1 inches across in the general plane of the bone, and at right angles to that 4·5, the difference being caused by a large process answering to a trochanter. The bone grows thinner, without much reduction of breadth for half its length, and then widens and grows thinner to the distal extremity. This extremity, formed in a general curve, has three facets, not always clearly marked, for adaptation to the two bones which represent tibia and fibula, the longest being anterior.

The femur is succeeded by two broad angular bones (tibia and fibula) in contact; a circumstance observed in several of the paddles of plesiosaurus of the middle and upper oolites, while in the lias these bones are always largely separated in the middle. In this our plesiosaurs make some approach to the pavement-like structure in the ichthyosaurs. There is a mark for a third smaller bone to be in contact with the femur.

No paddle has been found complete, or approaching to that condition in the Oxford district; but the bones rearranged appear to give a total length, if complete, of about 30 or 36 inches to this limb.

Counting 96 vertebræ at 1·6 inches, and the head, which cannot have been large, at 15 inches, we have, allowing for cartilage, 15 feet for the length of the animal, equal to five times the length of the hinder paddle, and fifteen times the length of the femur.

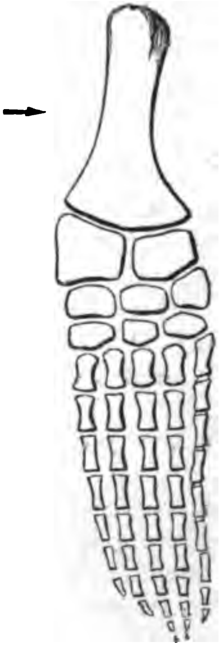

Diagram CXVII. Paddle of Plesiosaurus Oxoniensis. Scale, one-tenth of nature.

Taking the length of the femur equal to 100 inches, the breadth is 58, the whole paddle 277.

PLESIOSAURUS PLICATUS. *Phil.*

In the Oxford clay begins a series of plesiosaurians with transversely elliptical articulating faces to the vertebræ, especially the cervical and the anterior dorsals. Two species are known in the Oxford clay, others in the strata above, which differ in the relative lengths of the bodies. In no case, as yet, is the head recognized.

In the Oxford clay the species belonging to the 'ellipsospondylian' race are known only by vertebræ and ribs, though it may be possible hereafter to assign to these some of the limb-bones. If not identical with species in the Kimmeridge clay, they are very closely allied to them.

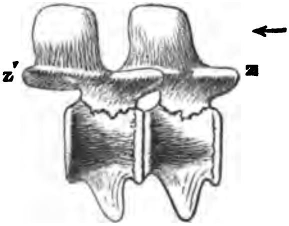

Diagram CXVIII. Cervical Vertebræ of Plesiosaurus plicatus, seen sideways. Scale, one-fifth of nature.

The faces of these vertebræ are so very gently concave as in some cases to appear almost plane; neatly bordered, wider than high, broadest below the centre, with marginal parapophyses. The sides are impressed above the parapophyses; the base is plano-concave, with two parallel depressions, and a pair of approximate large

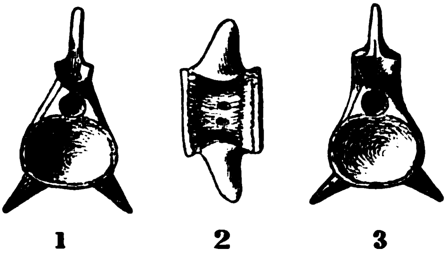

Diagram CXIX. Cervical Vertebræ of Plesiosaurus plicatus. Scale, one-fifth of nature.

1. Seen from behind. 2. Seen from below. 3. Seen in front.

foramina. The neural canal is striated lengthways on the floor, and in some vertebræ two foramina are observed. The smallest of these vertebræ are more concave on the faces than the larger.

Length of the smallest, 1·5 inches; breadth, 1·60; height to the canal, 1·30. The dimensions in the largest are, length, 2·10; breadth, 2·65; height, 2·00.

There are two anterior dorsals, incomplete only by loss of the neural spines.

Two foramina appear in the middle of the neural canal, and other two, as usual, on the lower face. The interval between these grows larger as we pass along the column, and they become lateral in the middle dorsals. Length, 2·2 inches; breadth, 3·05; height, 2·2 to the canal.

Two middle dorsals accompany the other vertebræ, incomplete in neurapophyses. These are longer than the anterior dorsals in proportion to the diameters; they have the same slightly concave articulating faces; the sides are impressed below the diapophyses, and in each depression is a foramen. Length, 2·4 inches; breadth, 2·8; height, 2·4.

PROPORTIONATE MEASURES OF THE VERTEBRÆ OF PLESIOSAURUS AND STENEOSAURUS IN THE OXFORD CLAY.

	Length for Standard.	Breadth, horizontal.	Height to Canal.
Plesiosaurus Oxoniensis, average	100	140	116
Cervical	100	145	118
Anterior dorsal	..	..	..
Dorsal	100	130	119
Caudal	100	145	110
Plesiosaurus plicatus, average	100	124	98
Cervical	100	121	95
Anterior dorsal	100	135	100
Dorsal	100	116	100
Caudal	..	..	..
Steneosaurus, average	100	83	83
Cervical	..	..	..
Anterior dorsal	..	..	..
Dorsal	100	80	80
Caudal	100	85	85

PLESIOSAURUS EURYMERUS. *Phil.*

A femur of this species of plesiosaurus, found at Bedford, and represented in the Oxford Museum by a cast in plaster, is unusually expanded at the distal, and small at the proximal extremity. The paddle presents a somewhat remarkable contraction in breadth where the tarsal bones begin. There appears to have been six of these, though only five remain, as in the Diagram above; while, to the extent of ten or eleven rows, two of the five toes can be traced in such arrangement as to form a long narrow paddle.

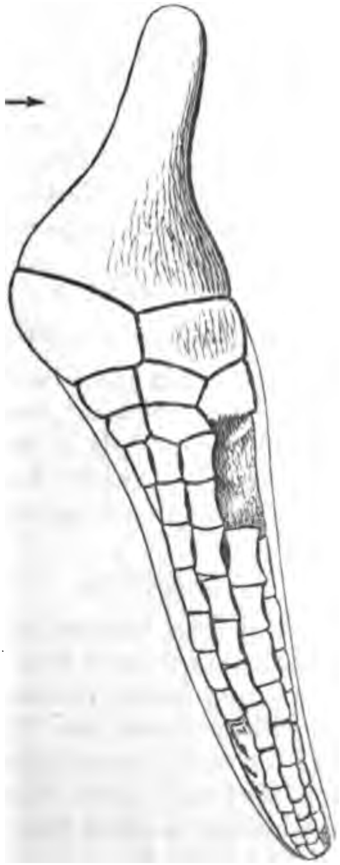

Diagram CXX. **Paddle of Plesiosaurus eurymerus, found at Bedford. Scale, one-tenth of nature.**

The femur is 16 inches long, and 11½ broad at the distal end. The two bones, which correspond to tibia and fibula, are 8 and 4·5 broad, while the tarsal bones together measure only 7·5 inches across.

Professor Owen observed this valuable specimen in the Woodwardian Museum at Cambridge, and places it near to Plesiosaurus dœdicomus, which has a femur expanded in the distal region; the expansion is, however, greater in this Bedford specimen. The proximal end shews no tuberosity; the distal ends have only two broadly sub-articulating faces, to fit with the remarkable tibia and fibula. The metatarsal row of bones has proximal facets of different forms to fit the tarsals. The phalangal bones are thick and solid; the five rows can be recognized, the largest bones being those of the fourth toe. The largest phalanx is 3·2 inches long, and 1·7 broad.

Taking the length of the femur, 100 inches, the breadth is 70, the whole paddle 287, the part beyond the femur 187.

PLESIOSAURUS TROCHANTERIUS. *Owen.* 1839.

(*Referred to Pleiosaurus in* 1841.)

A fine femur of this species, in the collection of the Earl of Enniskillen, was, he informs me, obtained from the Oxford clay at Christian-Malford[b]. A cast of it is in the Oxford Museum. The species occurs more abundantly in the Kimmeridge clay, and there are points regarding it which will be better discussed under that title.

PLEIOSAURUS.

Specimens of unconnected dorsal vertebræ have been occasionally brought by workmen reporting them to have been found in the Oxford clay pits, which have a decided pleiosaurian character, and correspond very much with specimens from Weymouth, and with others from Shotover. The small distance between the pits in the Kimmeridge and the Oxford clay in the vicinity of Heddington and Oxford, made me hesitate to admit these vertebræ as being truly from the lower deposit. But I am now satisfied. The species will be described under Kimmeridge clay.

A distinctly pleiosaurian cervical vertebra, with cicatrices of the neural and pleurapophyses, is placed in the collection, and marked from 'Rode, four miles south of Northampton.' It is very perfect, shewing in the broad flat neural floor two conspicuous foramina, and two others, as usual, on the lower surface. The pleurapophyses were supported by two extensive slightly prominent concave surfaces, divided by a deep horizontal furrow.

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[b] In Professor Owen's Report on Fossil Reptiles, 1839, this bone is said to have been from the Kimmeridge clay of Shotover Hill, where indeed others like it in many respects are found.

Length, 1·2 inch; breadth, 2·55; height, 2·2; concavity, 0·2.

There is, I believe, no Oxford clay *in situ* very near to Rode (Roade), but fossils of that deposit are frequent in the drift clays which abound there.

PLEIOSAURUS GRANDIS ? *Owen.*

A paddle, probably of this pleiosaurus, found near Peterborough

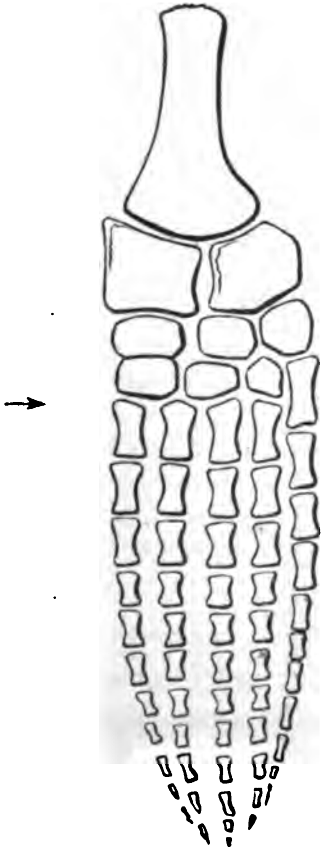

Diagram CXXI. Paddle of Pleiosaurus grandis. Scale one-tenth of nature.

by Mr. C. E. Leeds, M.A., of Exeter College, Oxford, presents the combination in Diagram CXXII., the length being 3 feet; but, if the toes were quite complete, probably the full length would have been 3 feet 6 inches, the femur being nearly 12 inches long, and 6½ wide at the distal end.

It was found with a lower jaw of pleiosaurus, which seems to agree generally with Pleiosaurus grandis of Owen, and the femur has considerable similarity to the specimens of that animal from the Kimmeridge clay of Shotover.

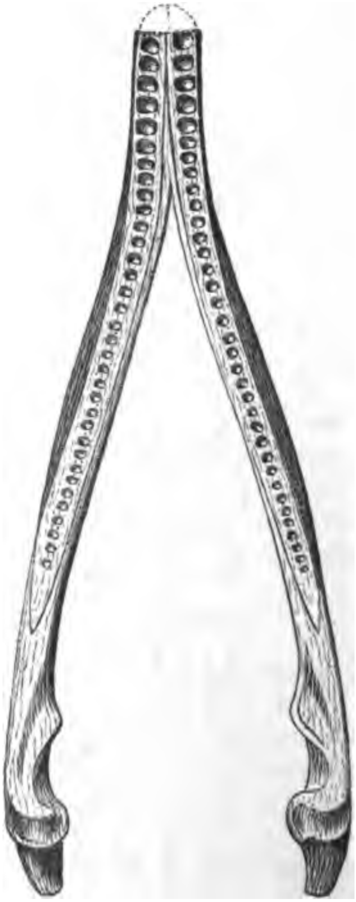

Diagram CXXII. Lower jaw of Pleiosaurus grandis. Scale one-tenth of nature.

STENEOSAURUS.

Twenty vertebræ have been obtained from the Oxford clay-pits at Long-Marston, not in very good condition, but quite certainly recognizable as of the true crocodilian type, and of the size and general aspect of a large specimen of the steneosaur of Shotover. Among them no cervicals appear, dorsals and caudals are numerous, there appear to be some lumbars, and there is one sacral vertebra.

The dorsals, distinctly recognizable as such, are eight in number, mostly preserving at least a portion of the diapophyses, which run out, at first broad and horizontal, and then bend downward to a contracted termination, in this resembling the large species of the Kimmeridge clay here named Steneosaurus palpebrosus. The height of the articulating faces of uncrushed specimens is equal to the cross diameter, but inferior to the length. These surfaces are moderately and equally concave. The greatest observed length is 2·75 inches, breadth and height 2·2. The transverse processes measure between the tips 9·5 inches. The body of the vertebra, as seen from below, is somewhat hour-glass shaped, and smooth.

The lumbar or posterior dorsal vertebræ, for it is not easy to distinguish in these specimens, are of nearly the same size, and equally concave on the faces as those mentioned above. There appear to be four such.

The sacral vertebra, posterior of the pair, has the articular face wider than high, and the diapophyses are directed downward in a remarkable manner so as to be inclined to one another 110°.

The anterior caudals are a little shorter, and more angular below, and marked by small hæmapophysial cicatrices. The articulating faces have the same degree of concavity. There are seven of these vertebræ. The animal must have been 20 feet long.

STREPTOSPONDYLUS CUVIERI AND MEGALOSAURUS BUCKLANDI.

One of the most remarkable of the many products of the clay north of Oxford is a series of bones of different parts of a saurian of moderate size, in the collection of Mr. James Parker. The various bones found together consist of parts of the head, vertebræ of the back, loins, and tail, bones of the fore-limb and of the hind-limb, for the most part in remarkable perfection. They present some difficulty. Teeth of Megalosaurus Bucklandi well characterized were scattered in confusion through the mass, and still remain attached to some portions. The portions of jaws found are also megalosaurian, one specimen being the anterior portion of one ramus of the lower jaw, much like that in the Oxford Museum, another being a pair of intermaxillary bones, with four tooth-sockets on each side, a tooth remaining in one.

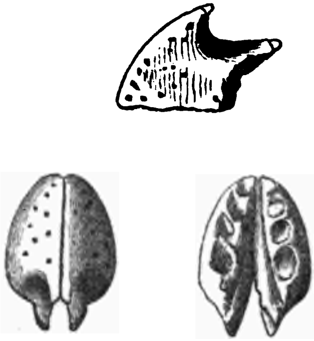

Diagram CXXIII. Anterior extremity of upper jaw of Megalosaurus. Scale one-fifth of nature.

Upper figure, a side view; left-hand figure, from above; right-hand, from below.

The fore-limb bones are one incomplete humerus, considerable portions of radius and ulna, and two phalangal bones. Of the hind-limb, a pair of femora complete, with a long spirally-ridged pubis laid by each; a pair of tibiæ, each having portions of a fibula near it, in one case almost the complete bone slightly displaced; an astragalus to match each tibia, in one case so placed as to justify the approximation originally suggested by Cuvier (see Diagram LXIV., *a*); five nearly complete and three broken metatarsals, several phalanges, and one claw-bone.

A nearly complete ilium of the general pattern of megalosaurus, and specially like the smaller one represented in Diagram LXVII.

All the bones mentioned are in point of magnitude about half the size (linear) of the largest megalosaurian bones of Stonesfield, and in relative proportions they are much in agreement with them. On comparing the bones of the hind and fore limbs, the former appear to be about twice as long as the latter; an interesting point in the study of the habits of life of the animal, but by no means peculiar to it. It is somewhat remarkable that the tibia is 19 inches long, the femur being 20, an approach to equality never observed in the specimens of megalosaurus from Stonesfield.

Along with these interesting bones, which go far to help to a right understanding of the structure of megalosaurus, and in particular to confirm the inference from the Stonesfield specimens of the greatly reduced anterior limb-bones, occurred as many as thirty-six vertebræ. Of these, nine appear to be cervical. The first and second vertebræ are not seen; the third is flat in front, concave behind; those which follow are convex in front and concave behind. Next follow several which are anterior dorsal; and these are concavo-convex, with the convexity forward as in Streptospondylus Cuvieri of Honfleur, to which indeed they offer the closest accordance, while no such vertebræ have been recorded from Stonesfield.

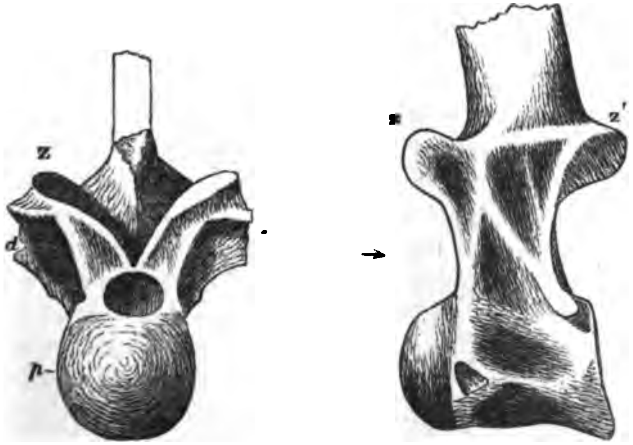

Diagram CXXIV. Anterior Dorsal Vertebra of Streptospondylus Cuvieri. Scale four-tenths of nature.

The left-hand figure shews the anterior aspect; *p* is the place of the parapophysis, *d* of the diapophysis, and *z* the expanding zygapophysis. The right-hand figure is a side view, shewing the buttress-like structure which supports *d*, the strongly-marked parapophysial scar *p*, and the articulations *z* and *z'*.

Others of these vertebræ, posterior dorsals and lumbars, are hour-glass shaped, with no parapophyses; concave behind, less concave or almost flat in front, or equally biconcave, much constricted between the ends. No such vertebræ have been obtained from Stonesfield.

Others again are clearly caudal, apparently not anterior but middle caudal, with a feeble transverse spine or ridge in the middle of the side, somewhat like a caudal vertebra of teleosaurus: no such has been seen from Stonesfield.

Finally, there are posterior caudals more after the style of crocodilian vertebræ, with extended posterior zygapophyses. No match for these at Stonesfield.

The vertebral system thus rapidly sketched corresponds exactly with what Cuvier said of a species of crocodile found at Honfleur[c], to which he assigned a head like that of steneosaurus, and to which the name of Streptospondylus Cuvieri is applied by Professor Owen[d].

In that fossil the cervical and anterior dorsal vertebræ are convex in front, even to become semiglobular; the posterior dorsal and lumbar bones lose this peculiarity, and become flat in front, and afterwards both ends are concave through the caudal series. Professor Owen refers to the species of Cuvier as being in evidence from the oolite of Chipping-Norton, by a fragment of a dorsal vertebra. He also speaks of a compressed tooth found with it resembling the well-known form of megalosaurus, and, like it, worn smooth and shining[e]. The description of the vertebra seems like that of a small ceteosaurus.

In the same mass was obtained a pair of incomplete bones which expanded and met on the median line of the lower side of the body, like ischia.

If all the bones and teeth thus described belonged to one animal, we should have an individual with the scapula, pelvis, limbs, jaws, and teeth of megalosaurus, and the vertebræ of streptospondylus. Is this possible? Deinosaur and crocodile combined in one animal, with excurrent analogy to birds of the struthious race? These apparently discordant elements were certainly found together; but necessity has sometimes brought into juxtaposition very strange fossil bedfellows.

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[c] Oss. Foss. t. iii. part 2.

[d] Reports of British Assoc. 1841, p. 88.

[e] Ibid. p. 89.

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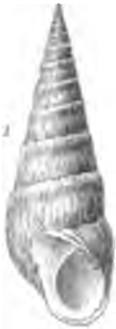
CORALLINE OOLITE *and* CALCAREOUS GRIT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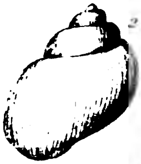
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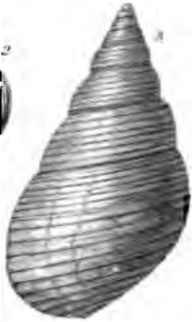
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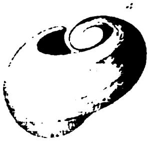
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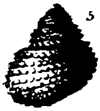
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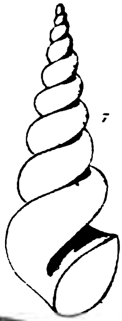
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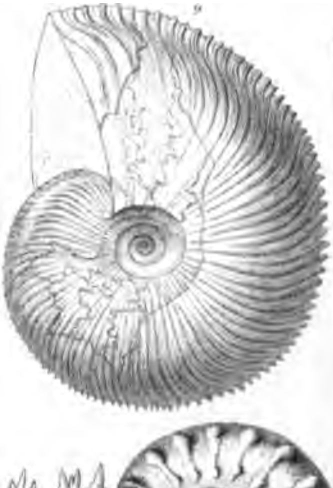
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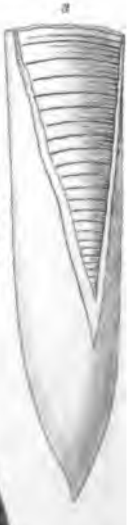
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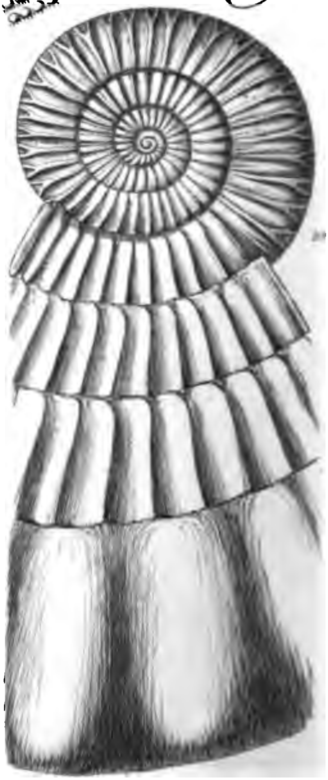
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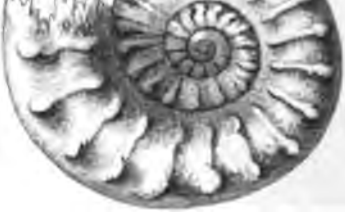

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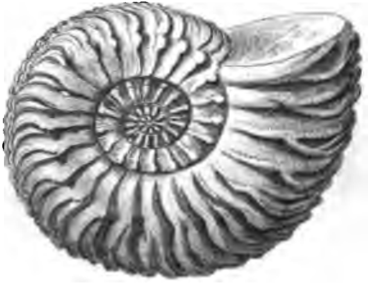

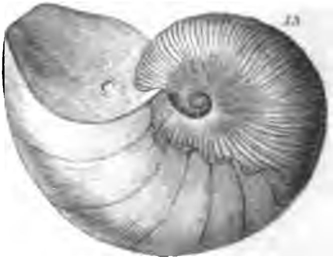
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Drawn by J.P

Engraved by J.B

Admitting, however, all the bones to belong to one animal, and regarding it as a megalosaurus, smaller and in some respects different from M. Bucklandi, we have only to adopt among the characters of that genus some forms of the vertebræ not previously known, and especially a peculiar pattern of cervical vertebræ, which were similar to but more in number than those in the neck of certain fossil crocodiles. The animal, on the whole, must have had the ornithic proportions and analogies of Megalosaurus Bucklandi.

REFERENCE TO PLATE XIII., REPRESENTING FOSSILS OF THE CORALLINE OOLITE AND CALCAREOUS GRIT.

1. Carpolithus plenus, fruit.
2. Cross section of the same.
3. Montlivaltia dispar. *a.* Septa.
4. Thecosmilia annularis.
5. Cladophyllia Conybeari.
6, 7. Thamnastræa arachnoides, to shew variations (from Steeple Aston).
8. Nastræa explanata.
9. Stylina De la Bechei. *b.* One of the cells (from Steeple Aston).
10. Comoseris irradians (from Steeple Aston).
11. Rhabdophyllia Phillipsii.
12. Cidaris Smithii, tubercle and ambulacral ray.
13. Cidaris florigemma, tubercle and ambulacral ray.
14. Hemicidaris intermedia, tubercle and ambulacral ray.
15. Hanipedina Marchamensis, a row of tubercles and half an ambulacrum.
16. Pygaster umbrella. *a.* An ambulacrum.
17. Pygurus costatus. *b.* The ambulacrum.
18. Echinobrissus dimidiatus. *a.* The rays.
19. Ostrea gregarea.
20. Pecten vimineus. *a.* The scaly ribs.
21. Gervillia aviculoides.
22. Lima rigida. *a.* The elevated striæ.
23. Lima læviuscula. *a.* The punctated striæ.
24. Pecten lens. *a.* The punctated striæ.
25. Modiola bipartita.
26. Astarte ovata.
27. Pholadomya obsoleta.
28. Myacites recurvus.
29. Opis Phillipsii.
30. Trigonia clavellata.
31. Arca æmula.
32. Trigonia clavellata.
33. Lithodomus inclusus.

REFERENCE TO PLATE XIV., REPRESENTING FOSSILS OF THE CORALLINE OOLITE AND CALCAREOUS GRIT.

1. Chemnitzia Heddingtonensis.
2. Natica arguta.
3. Phasianella striata.
4. Nerita brevispiralis. n. s.
5. Littorina muricata.
6. The beaded striæ.
7. Cast of the interior of Chemnitzia Heddingtonensis.
8. Belemnites abbreviatus.
9. Ammonites excavatus.
10. „ varicostatus.
11. „ perarmatus.
12. „ vertebralis.
13. Nautilus hexagonus.

CHAPTER XIII.

THE PORTLAND OOLITE PERIOD.

THIS series of oolite, sand, and clay is nowhere in England continuous for great spaces, except in its lower portion. The order of succession in the Oxford district is found to be thus:—

Sands with nodular concretions.
Rough calcareous beds.
Sands with nodular concretions.
Kimmeridge clay.

In Smith's 'Table of British Strata' the series is presented in the same form. In Shotover Hill the limestone beds are very incomplete, and indeed hardly separable from the large nodular concretions full of fossils which are so remarkable there. At Swindon the calcareous portion is, on the contrary, much more considerable, but hardly oolitic in texture.

KIMMERIDGE CLAY.

From the great cliffs of Kimmeridge in the Isle of Purbeck, which give name to the deposit, this clay is traceable (with no interruptions except such as arise from the unconformed over-extension of the chalk) into Yorkshire, everywhere preserving its characters of nearly uniform composition, great thickness, and peculiar organic fossils. The upper part is observed to be greenish in the vicinity of Oxford, and sandy, the tint being derived from glauconite, the common ingredient of greensand. In the railway cutting of Shotover Hill sandstones of a greenish tint interlaminated the upper parts of the clay, and announced the proximity of the next deposit by containing ammonites, pholadomya, and other fossils of the Portland group above.

The lowest part of the clay as seen near Oxford appears in the Heddington pits, resting on coralline oolite. About eight feet above the junction is a calcareous band eight inches thick. With these exceptions, and some parts more shaly than others, the clay appears nearly uniform in quality. There are probably two or three beds of Ostrea deltoidea, one near the base being often recognized, even as far to the north as Yorkshire. Here is to be seen in uncommon abundance, of large size, well and finely crystallized and beautifully clear, selenite, lying in the clay, and formed therein by processes long posterior to the deposition of the sediment, and still in progress of growth in contact with shells and bones. The thickness of this deposit in Dorsetshire may be taken at 600 feet; near Swindon it cannot be much less; but in Shotover Hill it does not exceed 100 feet on the western side. There is some difference between the fossil contents of the lower parts, which are few, and those of the upper parts, which are more numerous. This is the home of pleiosaurus, and that gigantic swimmer was accompanied by plesiosaurus, steneosaurus, dakosaurus, teleosaurus, and ichthyosaurus.

PORTLAND.

The junction of Kimmeridge clay and Portland beds is seldom to be seen near Oxford, except on the north-west side of Shotover Hill, where, in 1868, the following notes were written down, on occasion of examining for bones of steneosaurus found in the hard sandstone boulders.

4. Yellow clay with white irregular stripes and bands. No fossils; a few ironstone lumps and pebbles.
3. Yellow sand with bands of iron nodules and pebbles; irregular and discontinuous. It contains a white clay band.
    In this band, at the junction with the grey sand below, are large nodular blocks of gritty Portland rock, with the usual fossils. In one of these nodules were found the head and cervical parts of a steneosaurus.
2. Grey sand with undulated stripes and vertical tracts (like fissures filled) of yellow sand.
1. Kimmeridge clay, used for brick-making. The sand of No. 2 is employed to complete the bricks.
    The parts marked 3 and 4 seem to have slipped down hill, really belonging to the iron-sand series above. In a neighbouring pit two bands of nodules appear.

PORTLAND OOLITE AND SANDS.

In the Isle of Purbeck and the Isle of Portland are the greatest masses of this rock known in England, and they yield stone of the best quality for building. In the Vale of Wardour in Wilts, at Chicksgrove, limestone of the same age, not oolitic, is found: other detached masses at and near Swindon carry on the interrupted line of deposits, which reappears in Shotover Hill, at Garsington, Great Hazeley, Thame, and Quainton, and culminates in the prominent summit of Brill. These now widely-separated masses may have been once united; there is much diversity in the appearance of the rocks and their relation to the sands, but a great agreement in the organic contents. The mineral diversity may be explained, and the organic affinity accounted for, by local differences of limiting lands, and a general agreement of connecting water.

This water was marine, exclusively so, as it appears, for the sands below and above, as well as the rock in the midst. But there was some drift from the land to bring wood in fragments among the cardia, pholadomyæ, nerineæ, &c. of the Portland limestone and sand of Shotover Hill. This wood was attacked by xylophagous mollusks.

The marine condition here affirmed was everywhere quietly followed by an invasion of estuarine or even lacustrine formations. Thus in Purbeck, the Vale of Wardour, at Swindon, near Shotover, and near Aylesbury, and Brill, pale calcareous deposits with shells of fresh-water affinity followed without disturbance, in parallel strata, as if the area had been gently raised and the sea removed. To this point we must recur in the next chapter.

In the ascent of Shotover Hill the Portland rock is mainly represented by sands of a glauconitic character, enclosing hard spheroidal masses in a slight degree calcareous, and mostly very full of shells. They lie in two bands, as well as can now be seen, or rather as formerly could be seen, for many are destroyed. The masses are as much as five feet across and three feet deep. The shells are much intermingled, but offer no special marks of drifting; some bivalves have the parts in due place; wood occurs with them penetrated by xylophaga; there are occasionally bones, one reptile having the cranial and jaw-bones in connection, with cervical vertebræ adjacent.

The explanation once suggested was that these spheroidal masses were boulders (of an older part of the Portland series for example), but there is no reason to adopt such a notion. Admitting them to be concretions, round organic masses, there would be some difficulty in accounting for so many heaps of shells &c. at so many detached points, but that the same shells occur, though less plentifully, in the intervening sands. Some boulders are formed round bones chiefly. One way of viewing them is to regard them as held together by carbonate of lime, derived from decomposition of adjacent shells, or infiltrated from oolitic rocks above. Of these, in Shotover there is now barely a trace left, but there was formerly a small quarry of them, and I believe my memory assures me of lime-burning there half a century ago. It may be regarded as somewhat of a parallel case to what has already been mentioned under the head of the coralline oolite and calcareous grit, and it leads to the same conclusion, of great waste of the oolite in very ancient time, possibly at the conclusion of the long oolitic period. Thus, by meteoric following marine action, the patchy character and local incompleteness of the Portland oolite may be explained, and at the same time the unconformity of the greensand system, which is so remarkable in this region, accounted for.

Much in the same way, under the calcareous Portland rock at Swindon, lies an aggregate of sand and spheroidal or irregular, usually flattened, separate sandstones, which lie in planes not quite in conformity with the bedded rocks above. Similar appearances of concretionary sandstones are indeed almost never quite absent from any sections of the Portland sands about Thame, Aylesbury, and Brill, but the spheroids are rarely so large as in Shotover Hill.

Godwin Austen examined with care the sections presented at Swindon, and in the great quarry at the north-eastern extremity observed the following succession[f]:—

7. Thin-bedded calcareous sandstones, with marine shells, in a mass of sand.
6. Limestone containing apparently only fresh-water shells.

These parts of the section may be regarded as 'Purbeck beds.'

---

[f] Geol. Proc. 1850, p. 464.

5. Calcareous sand, passing up into limestone, 5 feet, containing a bed about 1 foot thick, almost entirely composed of *Terebra Portlandica.*
3. Clay containing a bed of *Ostrea falcata* and *Perna quadrata* (*mytilloides*), 1 to 2 feet.
4. Sand and sandstones, 25 feet; the lowest portion most fossiliferous. *Cardium dissimile.*
2. Pale blue stratified sandstone, 5 feet.
1. Thin seam of black sub-angular pebbles, of which a portion is always to be seen attached to the lowest masses of sandstone.

The same author gives a section of the detached deposit of Portland beds as observed at Bourton, a few miles east of Swindon:—

9. Stratified earthy oolite with *Ammonites*, and casts of Trigoniæ in abundance	8 feet.
8. Buff-coloured sands, with bands of pale yellow sand. No fossils	12 ,,
7. Flat-bedded white oolitic sand. No fossils	8 ,,
6. Rubbly oolite. Large *Pleurotomariæ*	1 ,,
5. Thick-bedded fossiliferous band	3 ,,
4. Ostrea and Perna bed	,,
3. Pebbles in calcareous beds. Fossils numerous	10 ,,
2. Fine sands	7 ,,
1. Kimmeridge clay	,,

At Great Hazeley the stone found between thick uniform grey sands, and iron sands and white clays like those of Shotover, is of good quality, and worked to a considerable extent for ashler, slabs, tombstones, and walling; being a fine sandy oolite, with layers of the ordinary shells, viz. trigoniæ, pectines, ostreæ, &c. It is obtained at some considerable disadvantage from under the thick cover of ferruginous sands.

At Brill the Portland rock is thin and lumpy, but white and very fossiliferous. It is extracted with difficulty from under a mass of laminated Purbeck clays and limestone, these being covered by thicker layers of sands and clays of the iron-sand series. Much the same characters accompany the rock at Quainton and other localities on the hills north of Aylesbury, beyond which it cannot be traced further to the east.

FOSSILS OF THE PORTLAND OOLITE AND KIMMERIDGE CLAY.

Abbreviations:—K. C. for Kimmeridge Clay; P. S. Portland Sands; P. R. Portland Rock. l., m., u. lower, middle, and upper.

PLANTS. Fragments of wood in each of the divisions.

ACTINOZOA. None have been collected in the Oxford district.

ECHINODERMATA.

Cidaris horrida. *Wr.* K. C. Wotton-Basset.
„ spinosa. *Wr.* K. C. u. Hartwell.
Echinobrissus Brodiæi. *Wr.* P. R. Brill.
Hemicidaris Brillensis. *Wr.* P. R. Brill.
„ Davidsoni. *Wr.* P. S.
Hemipedina Cunningtoni. *Wr.* K. C. u. Hartwell.
„ Morrisii. *Wr.* K. C. u. Hartwell.

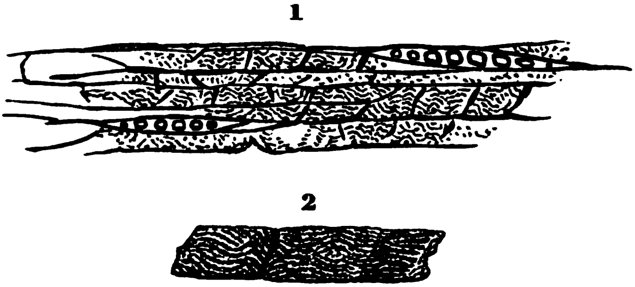

Diagram CXXV. Wood from Kimmeridge Clay.

1. Magnified view of a longitudinal and tangential section of wood found in the calcareous bed near the base of the Kimmeridge clay in Shotover Hill. It shews cross sections of the medullary rays, and longitudinal sections of the vessels interrupted by what seem to be cracks or fissures, though some are doubtless natural divisions. The diameters of the vessels are between $\frac{1}{800}$ and $\frac{1}{3000}$ of an inch. 2. More highly magnified, to shew the undulated and semispiral arrangement of what seem to be small dots $\frac{1}{10000}$ of an inch in diameter.

ANNELLIDA.

Serpula sulcata. *Sow.* K. C., P. R. Shotover.
„ tetragona. *Sow.* K. C. Wotton-Basset.
„ tricarinata. *Wr.* K. C. u. Hartwell.

CRUSTACEA. Fragments only as yet observed.

POLYZOA. None as yet collected.

BRACHIOPODA.

Discina Humphriesiana. *Sow.* K. C. Studley.
„ latissima. *Sow.* K. C. l. Shotover, u. Culham.
Lingula ovalis. K. C. l. Shotover.
Rhynchonella inconstans. *Sow.* K. C. l. Shotover.

The fewness of these invertebrata in this the uppermost of the oolitic groups corresponds with the idea of the gradual decay and final disappearance of the oolitic system of organic life and mineral deposits.

MONOMYARIA.

Exogyra nana. *Sow.* K. C. Shotover.
„ spiralis. *Goldf.* P. R. Brill.
Gervillia. sp. P. R. Shotover.
Gryphæa dilatata. *Sow.* P. R. Shotover.
„ virgula. *Defr.* K. C. l. Shotover, Hartwell, &c.
Inoceramus. sp. P. R. Shotover.
Lima obliquata. *Sow.* P. R. Thame.
„ rustica. *Sow.* K. C. u. Hartwell.
Ostrea deltoidea. *Sow.* K. C. l., m., u. Hartwell, Studley.
„ expansa. *Sow.* P. R. and P. S. Brill, Stone, Shotover.
„ falcata. *Sow.* P. R. Swindon.
Pecten arcuatus. *Sow.* K. C. u. Hartwell.
„ distriatus. *Leym.* K. C. u. Hartwell.
„ lamellosus. *Sow.* P. R. and P. S. Shotover, Brill.
„ nitescens. n. s. *Phil.* K. C. u. Wheatley cutting. P. R. Shotover.
Perna mytilloides. *Lam.* K. C. u. Hartwell. P. R. Shotover, Brill.
Pinna granulata. *Sow.* K. C. u. Hartwell.
„ lanceolata. *Sow.* K. C. u. Wheatley cutting. P. R. Shotover.

This list of species is much reduced from those of earlier date in the oolitic system. Ostrea deltoidea in the Oxford district is confined to the Kimmeridge clay; its ally, Ostrea expansa, to the Portland rock.

DIMYARIA.

Astarte cuneata. *Sow.* P. R. Shotover.
„ Hartwellensis. K. C. u. Hartwell, Culham.
„ ovata. *Sow.* K. C. u. Hartwell. P. R. Shotover.
Cardium dissimile. *Sow.* P. R. and P. S. Shotover, Brill, Swindon.
„ striatulum. *Sow.* K. C. u. Hartwell, Wheatley, Culham.
Cucullæa transversalis. n. s. *Phil.* P. R. Swindon, Shotover.
Cytherea rugosa. *Sow.* P. R. Swindon.
Isocardia minima. *Sow.* K. C. u. Hartwell, Wotton-Basset.
Leda Oxoniensis. n. s. P. R. Shotover.
Lithodomus. sp. P. R. Shotover.
Lucina lineata. *Sow.* K. C. Wotton-Basset.
„ Portlandica. P. R. Swindon.
Modiola bipartita. *Sow.* K. C. u. Hartwell, Wotton-Basset. P. R. Brill.
„ pallida. *Sow.* P. R. Brill.
„ pectinata. *Sow.* K. C. Wotton-Basset. P. R. Shotover, Swindon.
„ pulcherrima. *Goldf.* P. R. Shotover.
Myacites corbiformis. n. s. *Phil.* P. R. Shotover.
„ cuneatus. n. s. *Phil.* P. R. Shotover.
„ oblatus. K. C. Wotton-Basset.
„ parallelus. n. s. P. R. Swindon, Shotover.
„ recurvus. *Phil.* K. C. Wotton-Basset, Hartwell.
Mytilus unguiculatus. P. R. Shotover, Brill.

Pholadomya æqualis. *Sow.* K. C. Wotton-Basset.
„ inæqualis. n. s. *Phil.* P. R. Shotover.
„ rustica. n. s. *Phil.* K. C. Wotton-Basset. P. R. Shotover.
Pholas compressa. *Sow.* K. C. Shotover.
Tancredia tumida. P. R. Shotover, Hartwell.
Thracia depressa. *Sow.* K. C. l., m., u. Culham, Hartwell, Shotover. P. R. Brill.
Trigonia gibbosa. *Sow.* P. R. Shotover, Brill, Swindon.
„ incurva. *Sow.* P. R. Brill, Swindon.
Xylophaga. P. R. Shotover.

Few of these species are really very characteristic of this upper stage of the oolites. Trigonia gibbosa and Cardium dissimile mark the Portland rock, while Astarte Hartwellensis and Cardium striatulum belong to the upper part of the Kimmeridge clay. In this upper part at Wheatley the railway-cutting disclosed sandstone beds with fossils, some of them also found in the Portland rock above.

GASTEROPODA.

Alaria. sp. P. R. Shotover.
Buccinum naticoideum. *Sow.* P. R. Brill, Swindon.
Cerithium concavum. *Sow.* P. R. Tisbury, Wilts.
„ Portlandicum. *Sow.* P. R. Swindon, Shotover.
Chemnitzia gigantea. *Leym.* K. C. Wotton-Basset.
„ Heddingtonensis. *Sow.* K. C. Wotton-Basset.
„ inflata. n. s. *Phil.* Shotover.
Littorina muricata. *Sow.* K. C. Wotton-Basset.
„ paucisulcata. n. s. *Phil.* Shotover.
Natica elegans. *Sow.* P. R. Shotover.
Neritoma sinuosa. *Sow.* P. R. Swindon, Brill.
Phasianella striata. *Sow.* K. C. Wotton-Basset.
Pleurotomaria depressa. K. C. Shotover.
„ reticulata. *Sow.* K. C. Shotover, Swindon.
„ rugata. *Benett.* P. R. Swindon, Shotover.

In this scanty list of gasteropoda some species are marked in Kimmeridge clay which are more frequent in the subjacent oolites. They mostly occur in the lower part of the clay at Wotton-Basset, where they were collected for the National Geological Survey.

CEPHALOPODA.

Ammonites biplex. *Sow.* K. C. Nuneham. P. R. Swindon.
„ decipiens. *Sow.* K. C. Shotover.
„ Eumelus. *D'Orb.* K. C. Shotover.
„ giganteus. *Sow.* P. R. Swindon.
„ gigas. *Ziet.* P. R. Aylesbury.
„ Hector. *D'Orb.* K. C. u. Wheatley Cutting. P. R. Shotover.
„ pectinatus. n. s. P. R. Shotover.
„ rotundus. *Sow.* K. C. Aylesbury.

Ammonites superstes. *Phil.* n. s. K. C. Minety.
„ triplex. *Sow.* K. C., P. R. Swindon.
Belemnites excentricus. *Blain.* K. C. Shotover.
„ explanatus. *Phil.* K. C. Shotover, Waterstoke.
„ hastatus. *Blain.* K. C. Aylesbury.
„ Owenii. *Blain.* K. C. Shotover.
Trigonellites latus. *Park.* K. C. Baldon, Heddington.

The ammonites in this list (by no means including all the species) require much additional study before they can be regarded as fully determined. The species or group called A. biplex is unsatisfactory, and the gigantic sorts of Aylesbury, Swindon, and Portland are not clearly discriminated. The upper part of the Kimmeridge and the lower part of the Portland beds have species in common.

PISCES.

Asteracanthus ornatissimus. *Ag.* K. C. Shotover.
Chimæra Egertoni. *Buckl.* K. C. Shotover.
„ Townsendi. *Ag.* P. R. Shotover.
Gyrodus . . . sp. K. C. Shotover.
Hybodus acutus. K. C. Studley.
Lepidotus Fittoni. K. C. Hardwick, Bucks.
Pycnodus . . . sp. K. C. Shotover.
Sphærodus gigas. *Ag.* K. C. Shotover.

REPTILIA.

Chelonida. Remains of Carapace, &c. K. C. Shotover.

Crocodilida.

Goniopholis . . . sp. K. C. Hardwick.
Steneosaurus gracilis. n. s. *Phil.* P. R. Shotover.
„ palpebrosus. n. s. *Phil.* K. C. Shotover.
Teleosaurus asthenodeirus. *Owen.* K. C. Shotover.

Ichthyopterygia.

Ichthyosaurus æqualis. n. s. *Phil.* K. C. Shotover.
„ dilatatus. n. s. *Phil.* K. C. Shotover.
„ ovalis. n. s. *Phil.* K. C. Shotover.
„ thyreospondylus. *Owen.* K. C. Shotover.
„ trigonus. *Owen.* K. C. Shotover.

Sauropterygia.

Pleiosaurus brachydeirus. *Owen.* K. C. Shotover.
„ gamma. *Owen.* K. C. Shotover.
„ grandis. *Owen.* K. C. Shotover.
„ macromerus. n. s. *Phil.* K. C. Shotover, Swindon.
„ nitidus. n. s. *Phil.* K. C. Shotover.
Plesiosaurus affinis. *Owen.* K. C. Shotover.
„ brachyspondylus. *Owen.* K. C. Shotover, Cumnor.
„ carinatus. n. s. *Phil.* K. C. Shotover.
„ dædicomus. *Owen.* K. C. Shotover.
„ ellipsospondylus. *Owen.* K. C. Shotover.

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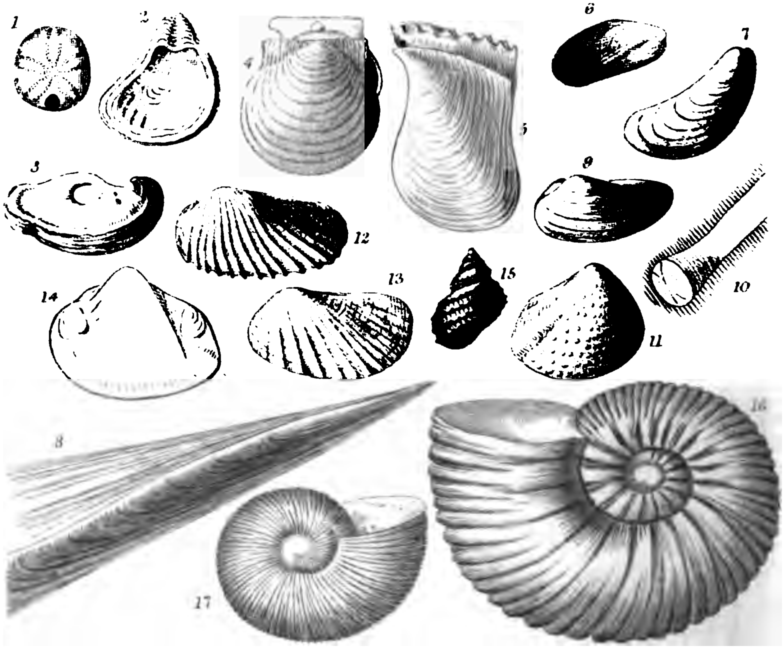
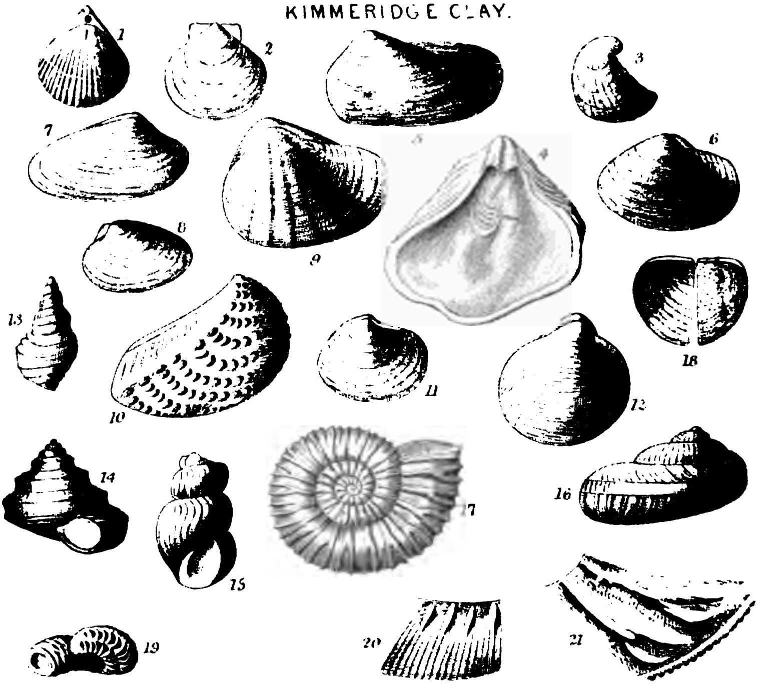
PORTLAND OOLITE.



KIMMERIDGE CLAY.



Drawn by J. P. *Engraved by J. [illegible]*

Plesiosaurus plicatus. n. s. *Phil.* K. C. Shotover.
„ trochanterius. *Owen.* K. C. Shotover.
„ validus. *Phil.* K. C. Cumnor, Baldon.
Deinosaurida.
Ceteosaurus longus. *Owen.* P. R. Garsington, Thame.
Megalosaurus Bucklandi. K. C. Swindon.

REFERENCE TO PLATE XV., REPRESENTING FOSSILS OF THE KIMMERIDGE CLAY AND PORTLAND OOLITE.

Portland Oolite.

1. Echinobrissus Brodiæi.
2. Ostrea expansa.
3. Exogyra sp.
4. Pecten lamellosus.
5. Perna mytilloïdes.
6. Modiola pectinata.
7. Mytilus unguiculatus.
8. Pinna lanceolata.
9. Myacites.
10. Xylophaga.
11. Trigonia gibbosa.
12. Pholadomya rustica.
13. „ inæqualis. n. s.
14. Cardium dissimile.
15. Littorina paucisulcata. n. s.
16. Ammonites Hector, with strong ribs.
17. „ pectinatus. n. s.

Kimmeridge Clay.

1. Rhynchonella inconstans.
2. Pecten nitescens.
3. Gryphæa virgula.
4. Ostrea deltoidea.
5. Myacites . . .
6. Thracia depressa.
7. Astarte Hartwellensis. Less angular on the posterior part than some.
8. Astarte ovata.
9. Pholadomya æqualis.
10. Trigonia incurva.
11. Astarte lineata.
12. Cardium striatulum.
13. Alaria.
14. Pleurotomaria reticulata.
15. Chemnitzia inflata. n. s.
16. Pleurotomaria.
17. Ammonites biplex.
18. Trigonellites latus.
19. Serpula sulcata.
20. Portion of Ammonites Hector, with fine ribs.
21. Portion of Am. superstes. n. s.

ICHTHYOSAURUS.

Remains of this genus of marine saurians are common in the Kimmeridge clay of Shotover and Cumnor; but only few cases occur even of several vertebræ in their true relative positions. Portions of the head may be said to be almost unknown; ribs, scapulæ, coracoids, and separate limb and paddle bones are occasionally found, but not so connected with the vertebræ as to render it worth while to describe them minutely. Diagrams of the more important will be added after the notices of vertebræ.

On Ichthyosaurian Vertebræ in the Oxford clay and Kimmeridge clay generally.

Placing before the eye about 250 vertebræ of ichthyosaurus collected from the clay pits round Oxford, there may be counted about 75 cervical, 75 anterior and middle dorsal, 100 post dorsal and caudal.

In this collection short chains of vertebræ may here and there be found, but only one of sufficient extent from one animal to make it a standard for the reunion of scattered elements. The series referred to was obtained from Cowley field, south-east of St. Clement's, where the upper part of the Oxford clay, dug for making bricks, yields abundance of Ammonites vertebralis.

It consists of the basi-occipital bone, followed by anchylosed first and second vertebræ, then by twenty other cervical and three anterior dorsals.

After an interval—estimated at five vertebræ—another series of ten dorsals, belonging to the same species, from the same clay at a greater depth, opened in a well at St. Clement's, comes in. Three cervicals belonging to the same individual satisfactorily confirm the identity of species, which resembles Ichthyosaurus trigonus of Owen. Thus we reach the 40th vertebra, and the full magnitude of the column of this individual.

After this, by frequent inspection of many detached vertebræ, we pass gradually to about the 60th, where a different general form sets in; soon after the lateral cicatrices unite, toward the basal edge; and finally this mark is lost toward the extremity of the tail, which is reached (probably) at about the 100th joint. Guided by the general view thus acquired, we may now consider the characteristics of species, which are almost wholly to be founded on the vertebræ.

ICHTHYOSAURUS TRIGONUS. *Owen.*

The Kimmeridge clay of Shotover and Swindon are the principal localities for this species, which is frequently met with, and of various sizes. The largest may have reached 20 feet in length, with a cervical 3·5 inches broad, posterior dorsal vertebra 5·25 inches; the smallest may have been 5 feet long.

Occipital region.—The basi-occipital is a hemispherical mass, with the usual lateral and inferior expansions, and a small groove above.

Cervical region. Three examples occur of the anchylosed first and second vertebra. One measures 1·00 inch across, another 2·90, a third 3·50 (including the apophyses). The anterior face is excavated; to fit the basi-occipital, the edge revolute. The outline of the faces is rather pentagonal than trigonal; the lower side slopes converging to form an angle exceeding 90° in the young, but falling short of that arc in the old. The neural canal ends in an arched outline against the cranial bone, and is gently concave, with several small foramina. In the young and middle-aged specimens the supplementary inferior bone can be traced, by suture, but not in the aged individual. In the young example each portion of the vertebra bears a neuro-spinal cicatrix; in the older specimens the anterior one fails or grows indistinct. The di- and parapophysial bases are somewhat irregularly placed.

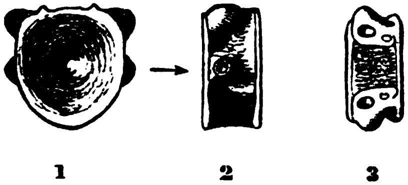


Diagram CXXVI. Ichthyosaurus trigonus. Scale one-fifth of nature.
1. Cervical vertebra (fourth), seen in front. 2. The same, seen on the left side.
3. The same, seen from above.

The vertebræ which follow have the same pentagonal outline of the faces, which are deeply concave for a space round the centre, and somewhat flattened toward the edge. Regarded laterally, the upper apophysial cicatrix is large, and tumid, and confluent with the base of the neural spine; the lower one more circular and smaller, both on or near the anterior edge. These characters continue with little change, except in the outline, which gradually becomes less pentagonal in figure, till the 22nd, the last of the cervical, which has a united base for the neural spine and diapophysis.

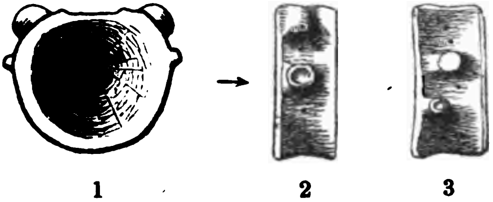


Diagram CXXVII.. Ichthyosaurus trigonus. Scale one-fifth of nature.
1. Last cervical vertebra, seen in front. 2. Seen on the left side. 3. Premedial dorsal of the same, seen on the left side.

Calling the vertebræ after this point dorsal, we observe the diapophysis to descend continually lower and lower on the middle of the side, and with the parapophysis, which is close to the anterior edge, forming a projection opposite the widest part of the vertebra, which is somewhat longer and wider in proportion than the bones more in advance (see Diagram CXXVII. fig. 3).

The 40th vertebra has the two apophyses approximate and lower down the side-slope; the outline of the face narrows upward, and widens downward to a kind of oval, the height being almost equal to the width, and double the length.

A vertebra which belongs to a point a little farther on, say the 45th or 50th, is of the large diameter of 5·25 inches, with a length of 2·6: its lateral apophyses are confluent into a sinuous arched cicatrix.

Still farther on, probably about the 60th or 70th vertebra, the lateral apophysis is single; a vertebra having this character is 4·8 inches, of equal height to the canal, and 2·25 in length. Others, of smaller size (3·4 across), have a length of 1·4.

After this the vertebræ, retaining nearly the same figure, become shorter, and often deeply depressed in the middle region; lastly, the lateral apophysis is lost, and small, short, somewhat oval excavated plates continue the series to the end, where the vertebræ again become relatively longer.

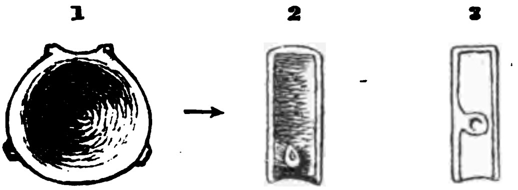


Diagram CXXVIII. Anterior caudal vertebræ of Ichthyosaurus trigonus. Scale one-fifth of nature.

1. Seen in front. 2, 3. Seen on the left side.

ICHTHYOSAURUS THYREOSPONDYLUS. *Owen.*

This species occurs at several points in the Kimmeridge clay near Oxford, as Winslow, Nuneham, Shotover, Wheatley; and it is found at Weymouth. Its most obvious character is the general shortness of the vertebræ, whose length is on an average less than two-fifths of the diameter. It is usually found to be of smaller size than other kindred remains, the largest known not exceeding 3·5 inches in diameter.

The cervical vertebræ of this group have the general form and structure of those of I. trigonus; but there are no examples of the first few vertebræ. An approach to pentagonal figure does however

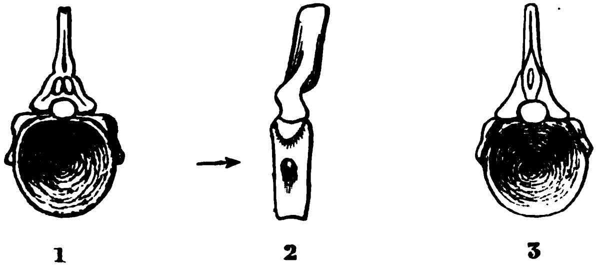


Diagram CXXIX. Ichthyosaurus thyreospondylus. Scale one-fifth of nature.

1. Cervical vertebra, seen in front; the zygapophyses almost vertical. 2. Seen on the left side. 3. Seen from behind.

occur, and one has the space round the centre of the disk deeply hollowed. They are very much shorter, remarkably so in the lower part, as if the neck were concave downwards. Length, 1·0 inch; breadth, 2·7; height to the canal, 2·5.

Anterior dorsals presenting a nearly circular excavated disk, with prominent lateral cicatrices, and similar proportions as to thickness, are followed by middle and posterior dorsals of similar characters.

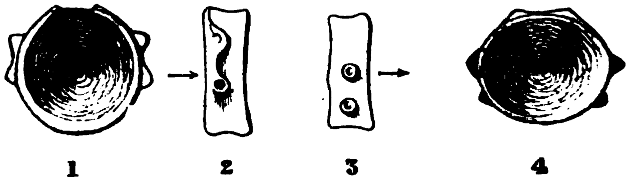


Diagram CXXX. Ichthyosaurus thyreospondylus. Scale one-fifth of nature.

1. Anterior dorsal vertebra, seen in front. 2. Seen on the left side. 3. Posterior dorsal, seen on the left side. 4. Seen in front.

Some of these are shorter in proportion than the others, the length being less than one inch to a breadth of 2·75. The last dorsals and the first caudals are contracted in breadth above, and enlarged below, as in I. trigonus; they are higher than broad, and have only small lateral cicatrices. Beyond this we have others of like form, but shorter, without any lateral cicatrix, and perforated in the centre. The length of these is only one-fourth of the diameter. It is probable that no further important variation occurred in the smaller end toward the extreme part of the tail.

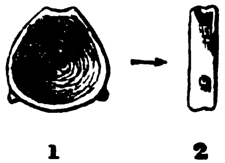


Diagram CXXXI. Ichthyosaurus thyreospondylus. Scale one-fifth of nature.

1. Caudal vertebra, seen in front. 2. Seen on the left side.

Indications of other species of Ichthyosaurus in the Kimmeridge clay.

ICHTHYOSAURUS DILATATUS. n. s.

A considerable number of dorsal and caudal vertebræ have a greater proportionate breadth than the corresponding bones in Ichthyosaurus trigonus, and some difference of outline of the faces. No other particular distinction appears constant. None of them have the exceptionally concave space about the centre of the face. They are thicker than the corresponding vertebræ of Ichthyosaurus thyreospondylus. In the preceding chapter the characters of the cervical vertebræ are considered.

ICHTHYOSAURUS OVALIS. n. s.

Other vertebræ of the anterior dorsal, posterior dorsal, and anterior caudal series have an oval outline of face, and are higher than broad. Two of the posterior dorsal vertebræ have the cicatrices placed very low on the body, the lower and smaller one quite on the anterior edge, in the situation occupied by the hæmapophysis of a crocodilian reptile. These specimens are from Swindon and Shotover. Another, of similar general aspect, comes from Kimmeridge in Dorsetshire.

Length of a posterior dorsal, 1·25; breadth, 2·85; height, 3·05.

ICHTHYOSAURUS ÆQUALIS. n. s.

One caudal vertebra, remarkable for neatness, is peculiar in the position of the single prominent excavated lateral apophysis, for it is placed almost exactly half-way on the body, or in the middle of the side. It is short, with flattened faces deeply excavated round the centre. Locality Shotover.

ICHTHYOSAURUS OR POLYPTYCHODON.

This remarkably conical tooth, with numerous regular nearly equal striæ drawn down its sides, has a largely expanded base and a central replacement. To which of the systems of vertebræ occurring at Shotover it belongs, if to any, there appears no method of determining.

It may be useful, however, to give it a name for reference, in hope that some day the jaw may be found in apposition with the vertebral column. The striated part or crown terminates toward the base in a regular curve across the conical surface, the several striæ coming there to a sudden truncation.

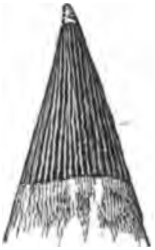


Diagram CXXXII. Tooth of Ichthyosaurus or Polyptychodon.

The diagrams which follow represent some bones of Ichthyosaurus, which cannot at present be referred to species, though it is probable they belong to Ichthyosaurus trigonus.

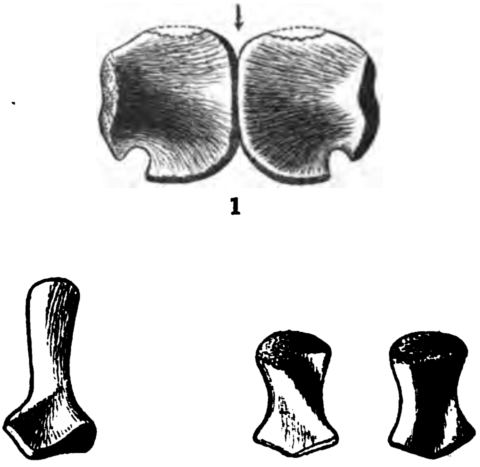


Diagram CXXXIII. 1. Coracoids. 2. Scapula. 3, 4. Humerus.

PLEIOSAURUS BRACHYDEIRUS. *Owen.*

The generic title of 'Pleiosaurus' is employed by Professor Owen, to whom we are indebted for nearly all that is known of it, to designate marine reptiles with a large head and short neck, and paddles much like those of plesiosaurus. The cervical vertebræ are short and broad, and have (*a*) simple or (*b*) divided marks of adherence of the pleurapophyses, these being robust and more or less cylindrical in figure. All the vertebræ are either plane or slightly concave on their articulating surfaces. The caudal vertebræ, as far as they are known with certainty, are short and broad. In several respects, as will be seen, this 'generic' group looks toward ichthyosaurus, which it rivals and even surpasses in magnitude.

The most important of all the specimens of large pleiosaurians yet discovered is certainly that which was found at Market-Rasen, in Kimmeridge clay, as usually admitted[a]. It furnishes indeed almost the only authentic collocation of the head with other parts of the body, and thus becomes a kind of index to the separate parts in other less complete examples. It contains the head; both jaws; eight or ten vertebræ of the neck; ten of the back; one of the tail. There are large bones regarded as femora by Owen, and several paddle bones. Some other parts of the skeleton are preserved in stony connection with a series of dorsal vertebræ[b].

The head, much shorter than the lower jaw, owing to the far extension backward of the branches of the latter, is somewhat crushed, but shews plainly the upper and inner surfaces, the sockets of teeth to the extent of twenty-six on one side, and several teeth in the sockets. The series of teeth is not complete.

The teeth were large in the anterior part, with an interspace between the fourth and fifth, and a contraction there of the jaw: after this the sockets for the teeth increase in size to the twelfth, and from the fourteenth they diminish continually, as we proceed backward, till at the twentieth they become sensibly smaller than in the fore-part of the jaw. The sockets are separated by thin septa, and are ranged in a broad groove, about three feet in length,

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[a] I have had some doubt on this matter, on account of the recurrence of a variety of Ammonites vertebralis, at Market-Rasen; the same variety being frequent in the upper part of the Oxford clay at Cowley.

[b] See Owen, Report on Fossil Reptiles, Part ii. 1841, p. 60.

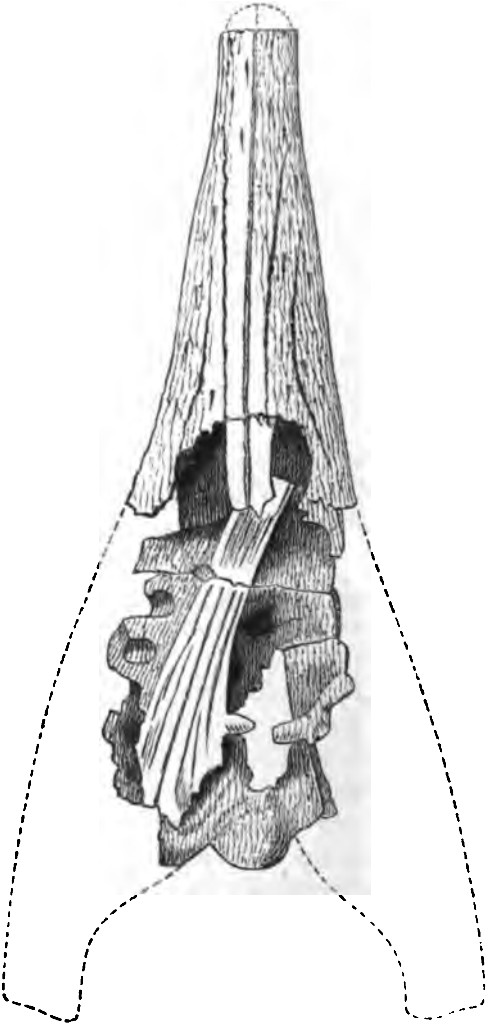

Diagram CXXXIV. Upper jaw of Pleiosaurus brachydeirus. One-tenth of nature.

between equally raised borders. The largest socket measures 1·6 inch in length, and 1·8 in breadth.

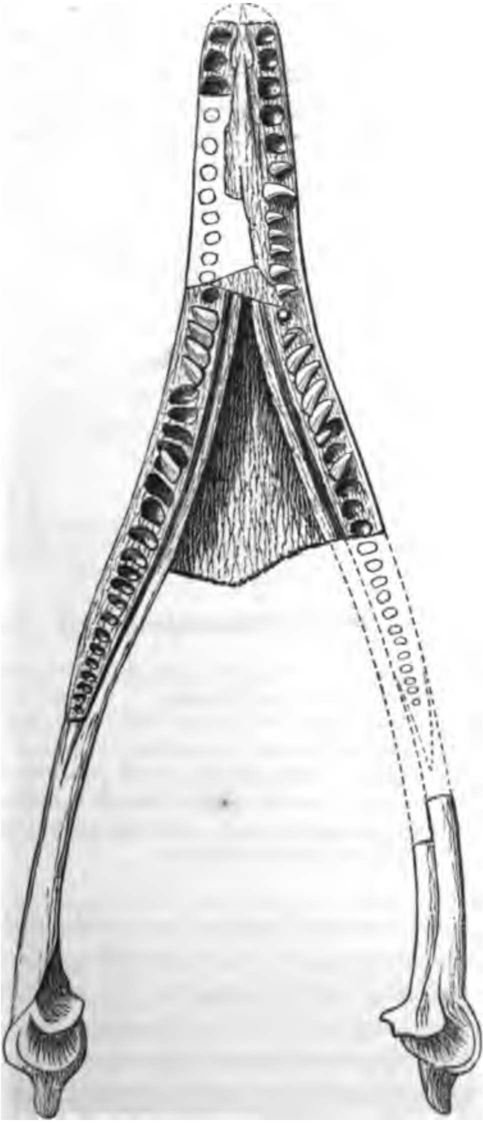

Diagram CXXXV. Lower jaw of Pleiosaurus brachydeirus. One-tenth of nature.

The lower jaw shews thirty-five sockets, and it is thought to be incomplete at the anterior extremity to the extent of three teeth.

The teeth have the peculiarity of being marked by two strong ridges passing from the apex, and dividing the crown or conical surface into unequal spaces, the outer one widest, flat or but little convex, and usually smooth. The fang is large and long, so that a very large complete tooth may be as much as 6 inches long and 2 in diameter.

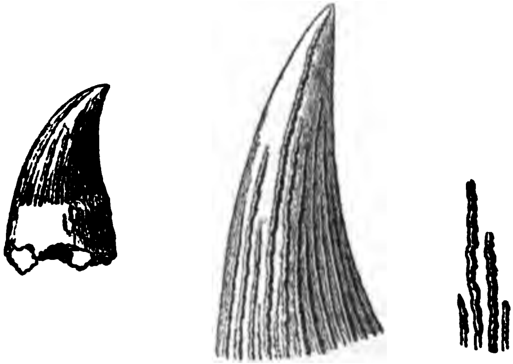

Diagram CXXXVI. Teeth of Pleiosaurus brachydeirus. Natural size.

1. Young or posterior tooth, shewing one of the continuous cariniform striæ on the crown, and others which do not reach the apex. 2. Older and probably more forward tooth; the carina roughly crenulated, with many striæ which admit of intermediate shorter ones near the base of the crown. The basal part of the tooth expands much, and is hollow. There are often three cariniform striæ proceeding from the apex; one, directed down the concave side, is usually shorter than the others. On this side the striæ are frequent; on the convex face few or even none between the carinæ, but a smooth or rugulose space.

Six or more of the cervical vertebræ near to the head have short elliptical bodies, nearly plane on the articulating faces, with large cicatrices on the sides, divided across, or rather a little obliquely. The lower surface is swollen in the middle, sometimes prominent on the anterior edge, depressed toward the sides, with two distinct foramina. The cicatrices for the neurapophyses are inclined to each other about 140°, and deviate from the plane of the neural canal 20°. That canal is striated lengthways, and expands at each end, most so retrally—there 1·25 inches broad.

Length, 1·6 inch; breadth, 3·9; height, 3·4 to the neural canal; or, if length = 100, breadth = 244, height = 212[c].

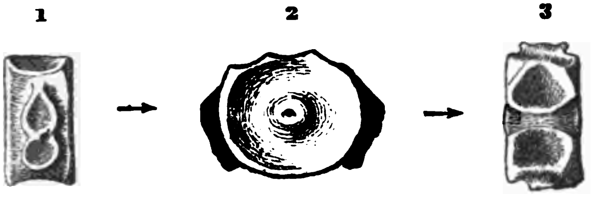

Diagram CXXXVII. Pleiosaurus brachydeirus. Scale one-fifth of nature.
1. Cervical vertebra, seen on the left side. 2. The same, seen in front.
3. The same, seen from above.

A seventh cervical vertebra, which perhaps follows immediately, has the lateral cicatrices not completely double; from this point these scars rise rapidly on the following vertebræ, and on the tenth it is a large oval space, no longer distinctly double. Of these vertebræ the central parts of the articular faces are tumid; the greatest diameter is above the centre; the thickness augments. They may perhaps be as well called anterior dorsals.

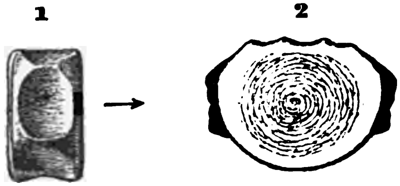

Diagram CXXXVIII. Pleiosaurus brachydeirus. Scale one-fifth of nature.
1. Posterior cervical, seen on the left side. 2. The same, seen in front.

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[c] Professor Owen describes an extraordinary cervical vertebra, possibly of this species, in the following words:—

'Perhaps there is no example, save the genus Pleiosaurus, in the whole class of reptiles, living or extinct, which has any of the vertebræ presenting such proportions as those of the following specimen in Dr. Buckland's collection from the Kimmeridge clay of Foxcombe Hill near Oxford. The breadth of the body of this vertebra is six inches; its depth, or vertical diameter, five inches; while in length it measures only an inch and a half.'

These measures give the unexampled proportions of—Length, 100; breadth, 400; height, 333.

It is to be regretted that this, and some other specimens of importance to the study of fossil reptiles, can no longer be found in Dr. Buckland's collection.

Length of these last, 2·0 inches; breadth, 4·2 (including the cicatrices, 5·0); height, 3·75; or, if length = 100, breadth = 210, height = 187.

Fifteen cervical vertebræ from Shotover, apparently belonging to this species, have the following proportions:—Length being 100, breadth varies from 293 to 208, and height from 243 to 188.

The dorsal vertebræ have the articular faces nearly plane and (except in the anterior bones which are wider) nearly circular, but truncated above by the neural cicatrices and canal. The neural canal is much contracted in the middle, and much widened behind. The neurapophysis is stated by Owen to rise 7 inches, so as to make the dorsal vertebra 11 inches high. The zygapophyses appear to have articulated by plane oblique surfaces, not in spoon-shaped processes as in plesiosaurus, but none are perfect. The sides and lower surface evenly convex, contracted in the middle, and smooth except at the edges, which are more or less roughly furrowed. Four foramina appear. The whole has a cylindrical aspect. The transverse processes are very prominent, directed upward, and have large convex articulating ends for round-headed ribs.

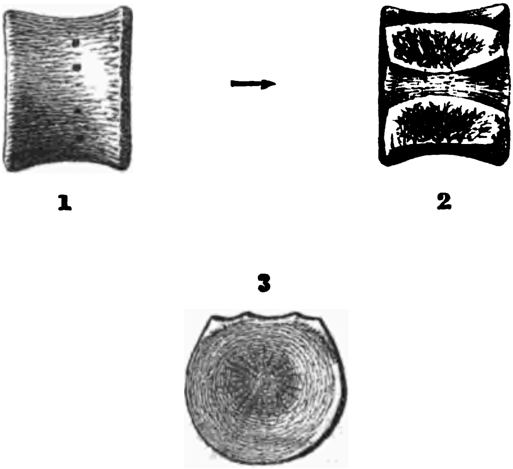

Diagram CXXXIX. Pleiosaurus brachydeirus. Scale one-fifth of nature.

1. Dorsal vertebra, seen from below. 2. The same, seen from above. 3. The same, seen in front.

Length, 2·85 inches; breadth, 4·15; height to the canal, 3·75.

An anterior dorsal, shorter and broader in proportion, measures 2·55 inches, 4·10, and 3·55.

Or, if length = 100, breadth = 146, height = 131.
„ 100, „ 161, „ 139.

Eight vertebræ from Shotover, apparently belonging to this species, have proportions as follows:—Length, 100; breadth, 119 to 143; height, 109 to 136.

A *lumbar* vertebra, quite perfect as to the body, the apophyses absent, but their places of attachment very clearly marked, is from Shotover Hill. The general figure and proportions agree with the dorsals already noticed. The articulating faces are a little concave, with small radiating undulations, and innumerable minute bordered open cells, or ends of vessels, like the fine hollow-celled oolite of Bath. The sides are very finely striated lengthways; there are as many as eight foramina. The neural canal widens very much behind. The neurapophysial cicatrix, nearly horizontal above, bends down in a loop on the sides, and is deeply pitted.

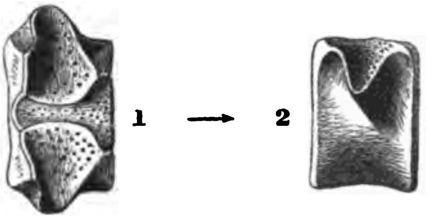

Diagram CXL. Pleiosaurus brachydeirus. Scale one-fifth of nature.
1. Lumbar vertebra, seen from above. 2. The same, seen on the left side.

One anterior *caudal* vertebra has articular faces nearly circular, the front nearly plane, the hinder surface a little concave; lower surface impressed on each side, with hæmapophysial scars.

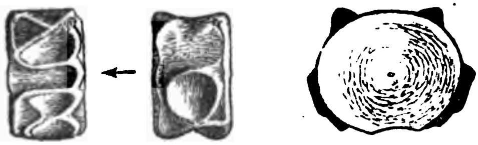

Diagram CXLI. Pleiosaurus brachydeirus. Scale one-fifth of nature.
Caudal vertebra, seen in front, on the left side, and from below.

Length, 2·25 inches; breadth, 3·85; height, 3·50; or, if length = 100, breadth = 171, height = 155.

Ribs occur at Shotover, not rarely, but probably they do not belong to this species. In the Market-Rasen specimen only fragments are recognised, with enlarged proximal heads.

A scapulo-clavicular bone, obtained at Shotover, which is in the museum of the Earl of Enniskillen, belongs, according to Professor Owen, to Pleiosaurus grandis. The bone is triradiate, the longest measure being 9 inches.

An ischium is mentioned by Professor Owen (1839) as having been found at Shotover, measuring 12 inches along the medial line, and 4 inches across the anterior edge. The inner margin is formed on a very convex curve, so as not to touch the opposite bone, except in the anterior part by a short symphysis. A bone corresponding to this was placed in the Museum in 1858.

A coracoid of considerable size, in two fragments, from Foxcombe, has been for several years in the Oxford Museum, and is represented in Diagram CXLII.

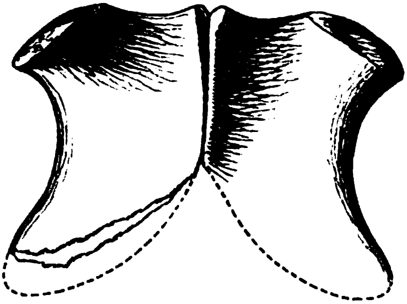

Diagram CXLII. Coracoids of Pleiosaurus. Scale one-tenth of nature.

The bone is, in a general sense, plano-concave, thick anteriorly and thin posteriorly, and smooth. The bones met with straight and plane faces for a considerable length (6·5 inches), and then diverged widely. The symphysis is so sloped that the bones met at an angle of 140°, so as to form a broad obtuse ridge, of great strength. The humeral articulation, formed on a curve, is 6·2 inches long, by 3·1 deep; the symphysial plane is 6·5 by 4·0. The curve is slight from the articulation to the symphysis. Length about 16·0 inches, breadth 10·2.

A nearly circular pubis, of which two specimens are in the Museum, one from Garsington, the other from Shotover, is a plano-undulate thin bone, 12·4 inches in the greatest diameter, with two thickened parts of the periphery, one (*s*) for the symphysis, the other (*i*) for opposition to the ischium. The arc included between the middle points of these surfaces is 72°. The depth of the bone at *s* equals 0·9 inches, at *i* = 2·0; the greatest thickness of the bone about the centre being 1·3, and the least, at the edges, 0·3. The ossification from the centre is marked by abundance of radiating grooves (Diagram CXLIII.).

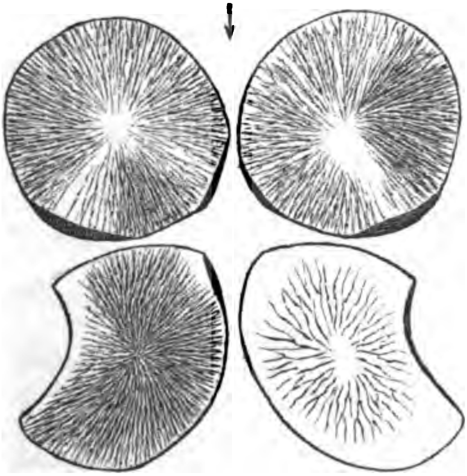

Diagram CXLIII. Pelvic bones of Pleiosaurus. Scale one-tenth of nature. Arrangement of pubic bones (above), and ischial bones (below).

A somewhat three-cornered broad thin bone, with an undulated surface, and a central point of fibrous ossification, usually regarded as an ischium, is represented in Diagram CXLIII. It is a solid smooth bone, formed in three curves, two convex and one concave. The symphysis is very short, curved, and cut at an angle of 70°; its depth being 1·25 inch. The anterior face of the bone is strongly marked for cartilaginous adherence; that part where the femur was articulated being 2·25 inches deep. The longest diameter 12·5 inches; articulating surface, 3·75; anterior curve, 4·5. There is another specimen less complete, about one-fifth larger.

On the supposition that this and the previously described bone constitute together the lower part of a pelvic arrangement, they are so placed in the above diagram (CXLIII.). The bone more resembles a monstrous tarsal, such as occurs in the middle line of the toe of some liassic plesiosauri; but that would indicate a paddle 28 inches broad, and a femur 24 inches broad, for which, at present, there is no authority.

A pubic bone, which came to the Museum complete as to figure in the clay, but so broken into many fragments partly decayed that it was not possible to replace the whole. Before the restoration, the exact figure was taken, and the vacant spaces were filled up to the true outline given in Diagram CXLIV.

It is a large nearly plane trapezoidal bone, with two convex and two concave sides, one angle being truncated by a slightly sigmoidal surface. The symphysial line is curved, its depth 1·4 inch; the articulating face is 6·3 long, and 2·4 deep.

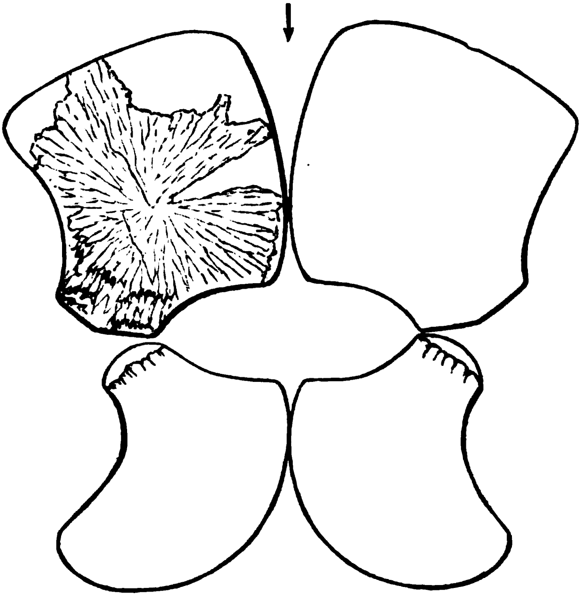

Diagram CXLIV. Pelvic bones of Pleiosaurus. Scale one-tenth of nature.

Arrangement of pelvic bones—the pubic above, the ischial below.

A broad, thin, plano-undulate bone, with an outline formed by two convex and two concave curves, the longest curve being a convex symphysial sweep, separated by concave outlines from a long narrow convex articulating face. The bone shews a central point of radiating vascular structure. The articulating face is above 6 inches long, and 2·0 deep: the deepest part of the symphysis 1·4 deep; the bone generally from 0·6 to 0·3. From the middle of the articulating face to the opposite margin, 12·0 inches; from the anterior part of the symphysis to the posterior and inner angle, 13·5 (Diagram CXLV.).

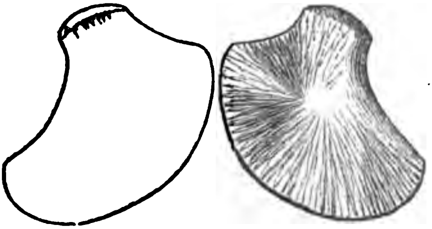

Diagram CXLV. Ischium of Pleiosaurus. One-tenth of nature.

It seems probable that this bone may be an ischium. It more resembles the ulnar or fibular bone of an ordinary plesiosaurus, but that would require the admission of a paddle 20 or more inches broad, which could not be adjusted to any femur or any phalangals at present known.

A larger outline of this bone may, conjecturally, be placed in relation to the pubis already described, as in Diagram CXLIV. A bone quite similar, and of the same dimensions, is described by Professor Owen in his Report on Fossil Reptiles for 1839.

Bones of the extremities.—There are portions of four first-bones of the leg, two of them nearly complete, among the instructive specimens from Market-Rasen. These are much alike, but one is larger than the other. The longer and larger bone may be assumed to be a femur, the smaller to be a humerus. The proximal end is injured in each case, but there is a separate fragment of a spheroidal shape and measuring 7·5 by 7·4 inches. There is no projecting trochanter. From this bulky head the shank proceeds in a sub-cylindrical form, and then passes, by continual thinning and widening obliquely, into a nearly semicircular margin, which in the middle is still 3·75 inches thick. Length, 26·3; breadth, 12·75.

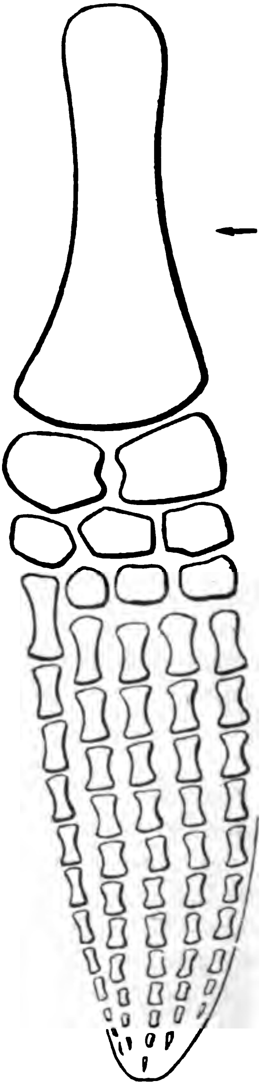

Diagram CXLVI. Paddle bones of Pleiosaurus brachydeirus. *Owen.*
Scale one-tenth of nature.

The other bone is 22 inches long, and 10·25 broad. If the length be called 100, the breadth is 47, thickness 14·2, and the whole paddle about 255 long.

Of the next bones, representing tibia and fibula (or radius and ulna), we have two sets; the former being 5 inches across, and transversely ovate; the latter subpentagonal, 4 inches across, and emarginate on the interior.

The thickness of these bones is 2·4 inches on the inner, but much less on the outer edge.

The arrangement of the bones of the tarsus (or carpus), as given in the diagram, is adopted after many trials and frequent comparisons with other paddles. The outer or hinder toe appears to have been attached to the first tarsal row, and by a longer metatarsal than the others. The metatarsals have their proximal ends modified to correspond with the tarsal bones. The phalanges are of the hour-glass shape, with broad squared ends. The longest (outer) metacarpal is 3·6 inches long, the larger phalanges 2·7 long, with a breadth of 2·0 at the proximal end, while the diameter in the middle is 1·0.

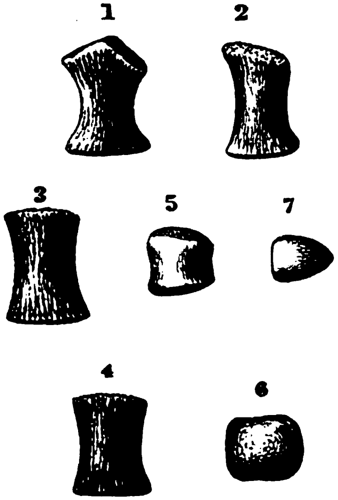

Diagram CXLVII. Phalangal bones of Pleiosaurus brachydeirus. Scale one-fifth of nature.

A specimen of the femur of this species (see Diagram CXLVI.

p. 352) was obtained at Swindon, 26·8 inches long, and 11·5 broad. Others were found at Shotover 18·5 and 19·5 long, and 8·0 and 8·5 broad. Tibial, fibular, tarsal, and phalangal bones corresponding to those from Market-Rasen occur at Shotover.

PLEIOSAURUS MACROMERUS. n. s.

The largest of the swimming reptiles found in the Kimmeridge clays near Oxford rivals in magnitude the great animal buried in the same strata in Dorsetshire. Huge paddles belong to both, but in neither situation is a complete skeleton known.

The cutting of the Great Western Railway laid open many interesting reliquiæ in the Kimmeridge clay near Swindon, and among them vertebræ, and leg bones of several large reptiles.

One of the leg bones, as already mentioned, belongs to Pleiosaurus brachydeirus ; but there is another of larger dimensions and different proportions, to which it seems probable that several characteristic large vertebræ ought to be associated, so as to constitute a well-founded separate species.

Of cervical vertebræ which appear to belong to this species we have six, from the anterior part of the neck, which, taken in order of magnitude, present the following dimensions. Two of them are from Swindon, and four from Shotover :—

a.	Length,	2·0 inches ;	breadth,	3·4 ;	height,	3·1.	Swindon.
b.	,,	2·0	,,	3·6	,,	3·4.	Shotover.
c.	,,	2·5	,,	4·4	,,	4·3.	Swindon.
d.	,,	2·7	,,	5·5	,,	5·3.	Shotover.
e.	,,	2·8	,,	5·7	,,	5·6.	Shotover.
f.	,,	2·8	,,	5·7	,,	5·6.	Shotover.

If length be taken at 100, breadth = 192, and height 185.

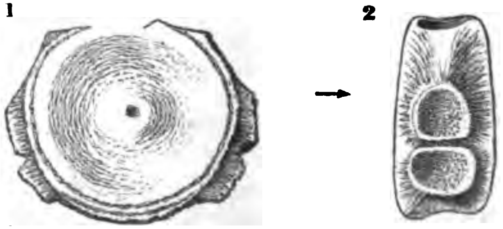

Diagram CXLVIII. Anterior cervical vertebra of Pleiosaurus macromerus. Scale one-fifth of nature.

1. Seen in front. 2. Lateral view.

These cervical vertebræ are remarkable for the clear division of the boldly-marked cicatrices into two nearly equal parts, so as to fit a large divided head of a rib. They are all somewhat short, nearly circular, roughly striated on the surface, and have a slight rising on the anterior edge of the lower surface, which in one specimen becomes a distinct boss.

The articular faces are slightly concave, some swelling up round the middle, which is commonly pitted; the edge is but little revolute, neatly bordered (mostly by a marginal groove). The circular sweep of the face is subtruncate above by the amplitude of the base of the neurapophysis.

Length of the largest, 2·8 inches; breadth, 5·65 (over the apophyses, 6·8); height to canal, 5·2. Length of the smallest, 1·9; breadth, 3·3 (over the apophyses, 4·1); height to canal, 3·0.

Two foramina appear in the floor of the neural canal, and usually one or two are observed on the sides.

Of posterior cervicals (rather than anterior dorsals) we have only a few specimens, characterized by large oval bases of the ribs, which are slightly emarginate, and thus gradually pass to the others, which have the cicatrix quite entire. In a fine specimen from Sandford the articular face is undulated; the centre usually rises in a large umbo, round which the disk is concave. The lower surface rises to a prominent tuberosity on the anterior edge.

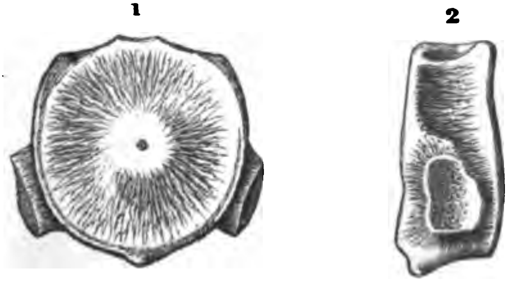

Diagram CXLIX. Posterior cervical vertebra of Pleiosaurus macromerus. Scale one-fifth of nature.

1. Cervical vertebra, seen in front. 2. The same, seen on the left side.

Length, 3·3 inches; breadth of articular face, 5·4; height, 5·5. The length of this vertebra is greatest in the lower part.

One dorsal vertebra from the railway near Swindon is of a magnitude and proportions suited to the others already mentioned. Nearly circular in section, and contracted in the middle of its otherwise cylindrical short body, it looks like a broad pulley wheel. The articulating faces are subtruncate above, the anterior one least concave; the edges rugose, not reflected.

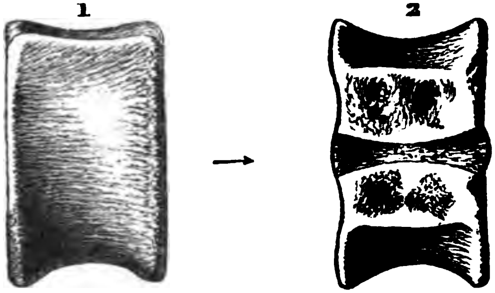

Diagram CL. Pleiosaurus macromerus. Scale one-fifth of nature.
1. Dorsal vertebra, seen sideways. 2. The same, viewed from above.

Length, 4·2 inches; breadth, 7·1; height to edge of canal, 6·9. If length be taken at 100, breadth = 168, height = 164.

A caudal vertebra, found in the gravel of St. Giles's, Oxford,

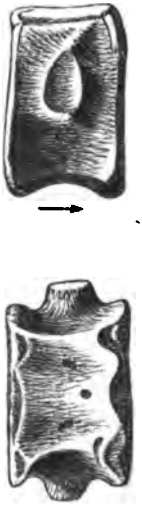

Diagram CLI. Pleiosaurus macromerus. Scale one-fifth of nature.
1. Caudal vertebra, seen on the left side. 2. The same, viewed from below.

is mentioned by Professor Owen in his Report on Fossil Reptiles

(1841, p. 63), as belonging to pleiosaurus. Another of the same kind was obtained from the Kimmeridge clay of Swindon. They appear to belong to the large animal already mentioned, Plesiosaurus macromerus. The articulating faces are swollen and prominent in the middle, and this umbo is encircled by a broad shallow depression within the raised and somewhat revolute border. The transverse processes were borne on projecting bases, from which they have been separated without fracture. The bases of the hæmapophyses were widely separated and placed at the ends of longitudinal ridges. The sides of the vertebra are much compressed.

Length, 3·0 inches; breadth, 4·8; height to the canal, 4·2, in the specimen from St. Giles's: or, if length be taken as 100, breadth = 160, height = 140.

Length, 3·0 inches; breadth, 5·2; height, 4·4, in the specimen from Shotover: or, if length be taken as 100, breadth = 173, height = 147.

Dimensions of large femur, length, 34·0 inches; breadth near distal end, 12·75; over proximal end (which is compressed), 8·4; in the middle of the shank, 7·25; thickness at the distal end, in the middle, 2·5. (See Diagram CLIX. p. 362.)

Comparing these proportions with those given for Pleiosaurus brachydeirus, the difference is very considerable. The general form is also different, the sides being more nearly on equal slopes and curves, especially in the smaller one; the bone much more compressed generally; and the distal edge fitted to thinner tibial and fibular associates. The head of the bone is in some degree ridged in the middle; and the interior surface for a space of 6 inches below the head is roughly ridged and furrowed, somewhat after the pattern of Pleiosaurus grandis, Owen, from which, however, it differs in form, relative breadth, and thickness. When placed by the huge femur (or humerus) from Kimmeridge, which is of fully equal size, a difference of form, though less marked, is quite manifest in the distal end, which in that species is not cut to a similar sweep, but has the usual doubly-cut edge for adaptation to the tibia and fibula. These species must, however, be nearly akin.

Of the femur (or humerus) there are three well-marked specimens, two probably making a pair of larger size; one smaller.

Small femur, 23·0 inches long; 8·5 wide at distal end; 4·2 at proximal end; thickness in the middle of the distal end, 2·5. Taking length at 100, the breadth = 37·5, thickness = 7·4.

PLEIOSAURUS GAMMA. *Owen.*

In the Oxford Museum are specimens of cervical, dorsal, and caudal vertebræ which belong to a definite species found in the Oxford clay of Weymouth, and in the Kimmeridge clay of Shotover. One of the cervical specimens has at some time received from Professor Owen the label 'gamma,' to which letter some resemblance may be imagined in the boundary lines of the lower cicatrices.

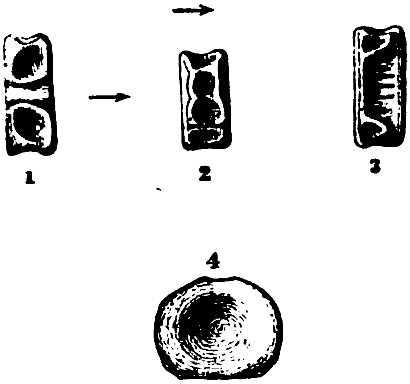

Diagram CLII. Cervical vertebra of Pleiosaurus gamma. Scale one-fifth of nature.
1. Seen from above. 2. Seen sideways. 3. Seen from below. 4. Seen in front.

These cervical vertebræ appear to be as short in proportion to the other dimensions as that species which was named by Owen P. brachydeirus, and shorter than any other species yet mentioned in this vicinity.

The length being 1·20 inch, breadth 3·05, and height 2·60, the proportions (100, 254, 217) agree fairly with those from Shotover referred to P. brachydeirus.

They differ in form, by an apparent straightness of the lower edge, caused by the very low position of the cicatrices, which are almost triple, the middle one deeply excavated. The articulating faces are gently and uniformly concave round the deeply pitted centre, and rounded at the edges.

The dorsal vertebræ which correspond to these are of different proportions: the length being 2·30 inches; breadth, 3·35; height to the canal, 3·32; to the border of the canal, 3·40. These proportions (100, 145, 144) agree well enough with those of P. brachydeirus.

Viewed from above, the neural canal is remarkably contracted in the middle; seen endways, the bases of the neurapophyses slope away from the middle more than in our specimens of P. brachydeirus, but this may vary along the column.

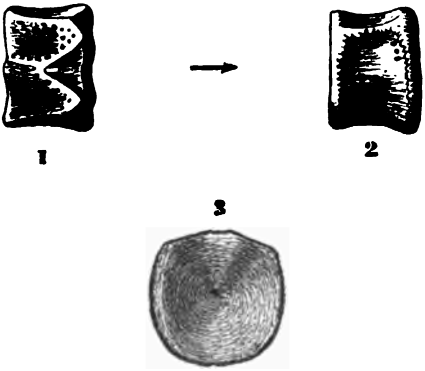

Diagram CLIII. Dorsal vertebra of Pleiosaurus gamma. Scale one-fifth of nature.
1. Seen from above. 2. Seen sideways. 3. Seen in front.

The articulating surfaces are gently concave round the centre, which is deeply pitted and somewhat wrinkled, two slight hollows diverging upward.

Of lumbar and caudal vertebræ corresponding to this species we have a series of ten. The largest and most forward in the column, having no marks of hæmapophyses, are nearly flat on both faces, which are deeply pitted in the middle.

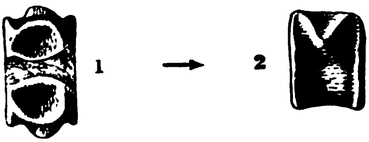

Diagram CLIV. Lumbar vertebra of Pleiosaurus gamma. Scale one-fifth of nature.
1. Seen from above. 2. Seen sideways.

Length, 1·80 inch; breadth, 2·45; height to canal, 2·25; to margin of canal, 2·45.

The vertebræ placed farther back about the middle have distinct surfaces for the hæmapophyses, and separate bases for the diapophyses, much resembling those of P. brachydeirus.

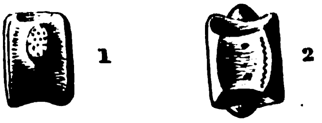

Diagram CLV. Caudal vertebra of Pleiosaurus gamma. Scale one-fifth of nature.
1. Seen sideways. 2. Seen from below.

Length, 1·75 inch; breadth, 2·60; height, 2·40 (2·50).

The articulating surfaces are nearly plane, and deeply pitted in the middle.

PLEIOSAURUS NITIDUS. n. s.

A few vertebræ of a fourth species, of smaller size than those already mentioned, occur in the Kimmeridge clay of Shotover—cervical, dorsal, and caudal—remarkable for neatness and comparative smoothness of surface.

The *cervical* vertebra has oval faces of articulation, remarkably rounded and somewhat plaited at the edges, flat over most of the surface, but depressed and somewhat puckered in the middle. The neural canal is unusually wide, flat, and expanding retrally, with two foramina. The diapophysial cicatrix is long, not deep, but marked across so as to indicate division in a more forward-placed vertebra.

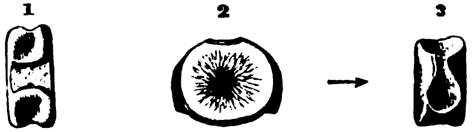

Diagram CLVI. Cervical of Pleiosaurus lævis or nitidus. Scale one-fifth of nature.
1. Seen from above. 2. Seen in front. 3. Seen sideways.

Length, 1·2 inch; breadth, 2·6; height, 2·15 (2·20).

The dorsal vertebra has several points of peculiarity. Regarded on the upper face, the spoon-shaped base of the neural canal, which from nearly parallel edges in the anterior half expands to two and even three times the width in the posterior part, approaches the structure of P. gamma, where the middle of the canal is very narrow, or actually reduced to a line.

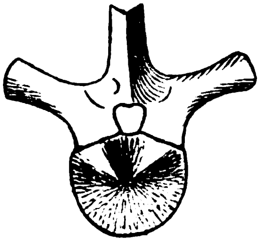

Diagram CLVII. Dorsal vertebra of Pleiosaurus nitidus. Scale one-eighth of nature. Seen in front, with the neurapophysis and diapophysis in place.

Looked at in front, the neural canal is not circular, but widest above: the neurapophysis has a lanceolate section and a longitudinal vertical notch or groove: the diapophyses are oval in section. The articulating face is nearly plane, but pitted in the middle; something more than a half ellipse in outline, with two edges sloping upwards to the neural canal (Diagram CLVII.).

Seen sideways or from below, it differs little from that of P. gamma.

Length, 1·9 inch; breadth, 3·00; height, 2·60 (2·70).

The caudal vertebra (anterior), somewhat larger than the others, agrees in general character with them; having a similar neural canal, and articulating faces similarly pitted and bordered. The cicatrix for the transverse process, nearer to the anterior side, is sharply bordered. The lower surface, rather plane, is bordered by the loops of the hæmapophysial attachments.

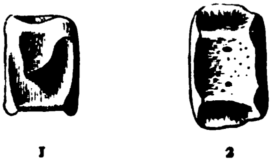

Diagram CLVIII. Caudal vertebra of Pleiosaurus nitidus. Scale one-fifth of nature. 1. Seen laterally. 2. Viewed from below.

Length, 1·9 inch; breadth, 2·9; height, 2·4 (2·5).

PLEIOSAURIAN AND PLESIOSAURIAN FEMORA, HUMERI, AND PHALANGES.

Of these the clay pits of Shotover, Wheatley, and Cumnor have yielded a considerable number, and they seem to belong to several species; but to which of the species respectively mentioned in the preceding pages is for the most part uncertain. Besides the very large limb-bones of Market-Rasen (Diagram CXLVI.), we have several others of different sizes and forms, represented in outline in the following diagrams.

To distinguish femora and humeri is not always easy; the best rule, as it appears to me, derived from a study of the complete skeletons of plesiosaurs in the lias, is to regard those as humeri which have the distal articulating faces very unsymmetrical, and the anterior and posterior outlines very unequally curved.

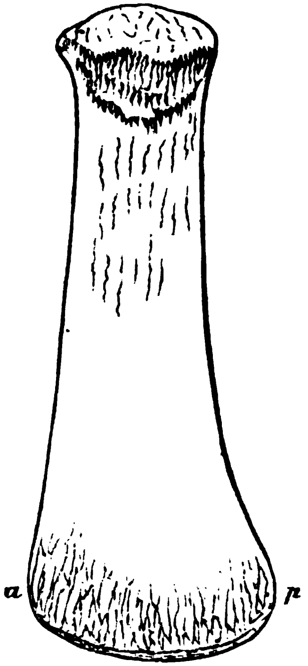

Diagram CLIX. Femur of Pleiosaurus macromerus. Scale one-tenth of nature.

The proximal extremities vary much, some being nearly spheroidal, others marked by a double-curved slope, others bicipital through a large trochanterial prominence. The distal extremity is defined by a simply convex curve, or has two broad emarginations, or two broad and one narrow emargination. The shank is laterally compressed in some, but has nearly a circular section in others.

The largest, from Swindon, is represented in Diagram CLIX., and is referred to as P. macromerus, p. 357.

The dimensions have been given on p. 357. There is a rough wrinkled surface below the head, on the outside. There is a fragment of a larger specimen. The small depth of this bone at the proximal end is remarkable.

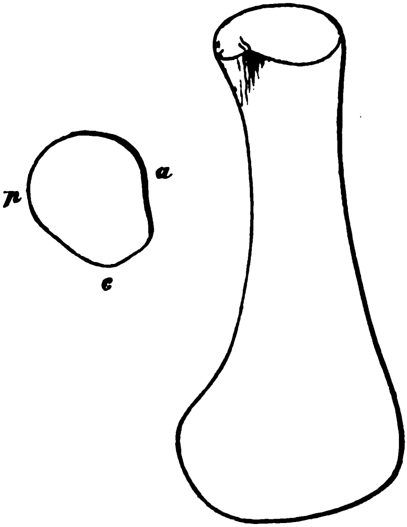

Diagram CLX. **Humerus of Pleiosaurus brachydeirus. Scale one-tenth of nature.**

The dimensions have been given on p. 354.

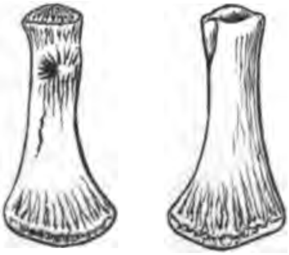

Diagram CLXI. **Femur of Pleiosaurus grandis.** *Owen.* 1838. **Scale one-tenth of nature.**

These drawings are from casts of the specimen described by Professor Owen.

Length, 12·4 inches; breadth at the distal extremity, 5·8; depth of the same, 2·3; diameters of the head, 4·0 by 3·3; a prominent half-encircling wrinkled and pitted ridge, three inches on the inside below the head. The distal articulating face is a little concave anteriorly, convex posteriorly. Some specimens are 16 and 18 inches long. From Shotover.

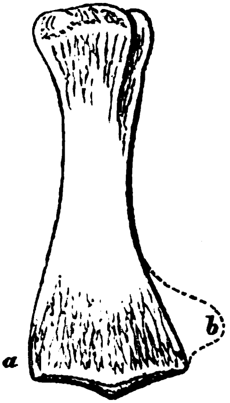

Diagram CLXII. Humerus of Pleiosaurus (?) trochanterius. *Owen.* Scale one-tenth of nature.

Length, 24 inches; breadth of the distal end, 10; depth of the same, 2; diameters of the proximal end (bicipital), 6 and 5; of the shank where smallest, 4.

The head is remarkable for the great size of a trochanterial projection, which rises higher than the proper articulating head on the exterior side, and is separated from it, somewhat as the great trochanter of iguanodon is outstanding. On the inner side is a wrinkled surface below the head.

The bone grows thinner and wider toward the distal end, where two excavated articulating faces appear, each marked by a longitudinal median prominent ridge. These faces meet to constitute a very distinct transverse salient keel.

The cast of the specimen described by Professor Owen [d] agrees with specimens not so large from Wheatley and Foxcombe, excepting that the posterior edge of his specimen was imperfect, while in these it is excurrent from the general outline of the distal extremity, which in consequence has three excavated surfaces of articulation. One of these is represented below.

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[d] See note as to the locality, p. 316.

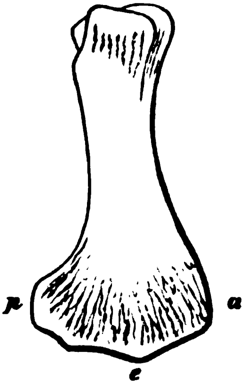

Diagram CLXIII. Humerus of Pleiosaurus trochanterius. Scale one-tenth of nature.

Length, 18·0 inches; breadth of distal end, 9·7; depth, 2·4; diameters of the head, 6·5 and 5·5 (or 5·8 and 4·8); of the shank where smallest, 4·0 (or 3·6). From Foxcombe, Wheatley, &c.

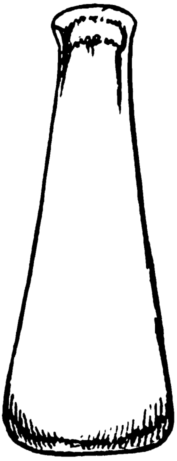

Diagram CLXIV. Femur of Pleiosaurus æqualis. n. s. Scale one-tenth of nature.

Length, 23 inches; breadth of distal end, 8·5; depth there, 2·5;

diameter of the proximal end, 4·2. A smooth almost straight-sided bone regularly expanding from the upper part. From Swindon.

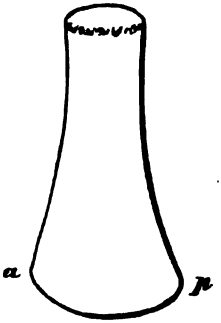

Diagram CLXV. Femur of Pleiosaurus simplex. Scale one-tenth of nature.

Length, 16 inches; breadth of distal end, 7·6; diameter of head, 4·0; of shank where least, 3·5. This is a smooth bone with little mark of tendinous attachment. From Shotover. Specimens only half or even one-third of this size occur in the Coralline oolite and Oxford clay.

PLESIOSAURUS AFFINIS. *Owen.*

Under this head Professor Owen describes a femur from Shotover Hill as like P. trochanterius, but smaller, and with a less prominent trochanter. There is a transverse rugosity on the inner side of the upper fourth of the bone. In this it resembles P. grandis. Its length is 8 inches.

PHALANGAL BONES OF PLEIOSAURUS.

Phalangal bones occur in considerable number, but it is rarely the case that they can be obtained in such a manner as to admit of being replaced in their true relative situation. It is for the most part uncertain to what species they belong. Only one specimen has yet occurred—that from Market-Rasen—which presented no difficulty in this respect. The large bone represented in Diagram

CLXVI. is, like many others, of a depressed hour-glass form, corresponding to some equally depressed tarsal and cnemial bones,

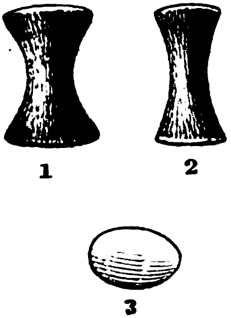

Diagram CLXVI. Pleiosaurus macromerus. Scale one-fifth of nature.
1. Phalangal bone, seen from above. 2. The same, seen edgeways. 3. The terminal surface.

and the large but not thick femora of the great pleiosaurus of Swindon.

Length, 3·5 inches; greatest breadth, 2·6; smallest breadth, 1·1; depth, 1·7.

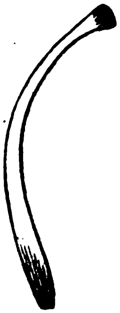

Diagram CLXVII. Rib of Pleiosaurus, which appears to have been somewhat cartilaginous toward the extremities. Scale one-tenth of nature.

PLESIOSAURUS.

Under this title those marine reptiles are here included which had a small head, long neck composed of many vertebræ, and extended paddles with five rows of toes. The cervical vertebræ are small near the head; more or less concave on the articulating surfaces. The dorsal vertebræ are slightly concave or almost plane on the articulating faces. The anterior zygapophyses unite into a spoon-shaped projection.

In one section (*a*) the cervical pleurapophyses are seated on a divided cicatrix; in another (*b*) they have a single horizontally-elongated marginal surface of attachment, to which they are usually anchylosed. To this section all the species in the strata near Oxford belong; the lias contains examples of the other section.

PLESIOSAURUS BRACHYSPONDYLUS. *Owen.*

The Oxford collection contains a considerable number of cervical, dorsal, and caudal vertebræ of a species approaching to or equalling in size the pleiosaurs of Shotover.

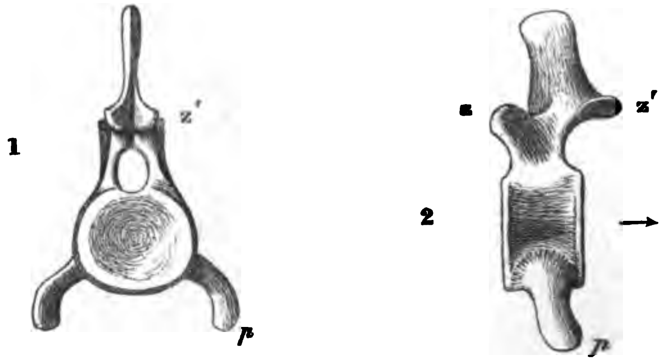

Diagram CLXVIII. **Cervical vertebra of Plesiosaurus brachyspondylus. Scale one-fifth of nature.**

1. Seen behind. 2. Seen on the left side.

Many cervical vertebræ of unequal size, constituting a broken series, mostly anterior, but not beginning very near the head, have been obtained from Shotover. The smallest has a breadth of 1·95 inches, and a length of 1·75; the largest is 3·2 inches broad, and 2·15 long. In all the height is less than the breadth, the length being proportionally greatest near the head. The articulating faces are equally concave, more or less oval, neatly bordered; sides gently depressed; hæmapophyses bent down; two large foramina beneath; zygapophyses divided in the middle; the anterior pair deeply spoon-shaped.

Several dorsals are at present known from Shotover Hill, twelve of them connected in a series; there are also nine others detached from Shotover and Foscombe, all found in Kimmeridge clay. Three other dorsals found at Marcham appear to agree with them, and may be regarded as posterior dorsals.

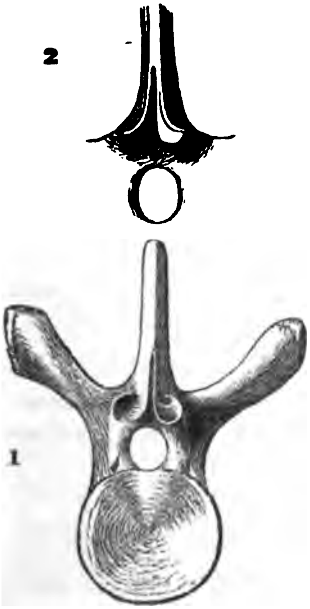

Diagram CLXIX. Dorsal vertebra of Plesiosaurus brachyspondylus.
Scale one-fifth of nature.

1. Seen in front. 2. The posterior zygomatic process.

In the series of twelve, the breadth is somewhat greater in the forward vertebræ, the length somewhat greater in the hinder ones.

In No. 1. Length, 2·3 inches; breadth, 4·25; height to canal, 3·6.

In No. 6. Length, 2·5 inches; breadth, 4·00; height to canal, 3·1.

In No. 12. Length, 2·55 inches; breadth, 3·82; height to canal, 3·35.

The articulating faces are nearly circular.

The three vertebræ from Marcham, posterior dorsals, have the zygapophyses widened and reduced in prominence. With the same breadth, they are deeper and longer than the Shotover examples. Length, 3·03 inches; breadth, 4·20; height to canal, 4·10.

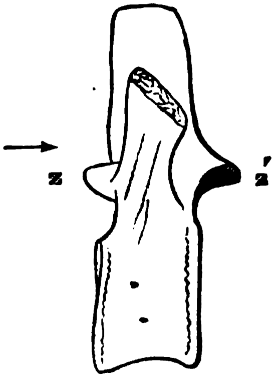

Diagram CLXX. Dorsal vertebra of Plesiosaurus brachyspondylus. Seen on the left side.

In proportion to the dorsal vertebræ of some other species, these may be regarded as short; and it has been usual in the Oxford collection to mark them by the name Plesiosaurus brachyspondylus, given by Professor Owen [d].

PLESIOSAURUS VALIDUS. n. s.

Of this large and fine species the clay pits of Shotover, Cumnor, and Baldon have furnished many examples. They include two sets of cervicals, a few dorsals and lumbars, and a considerable series of caudals. The cervicals begin small and increase regularly through a series of twenty-six, without in that length undergoing much change of form, except that in the last the lateral cicatrix has ascended considerably toward the dorsal region, and is almost connected with the base of the neurapophysis.

[d] Report on Fossil Reptiles, 1839.

Allowing two for the anterior missing vertebræ, we shall have in all, probably, twenty-eight unequivocal cervicals; and perhaps one or two more may have deserved to be classed in this category rather than as anterior dorsals.

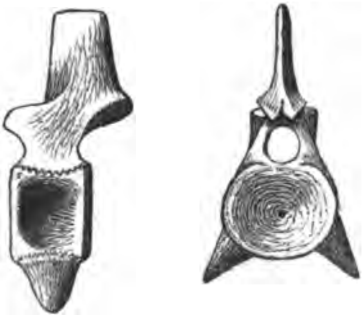

Diagram CLXXI. Cervical vertebra of Plesiosaurus validus. Seen on the left side and behind.

These vertebræ have neatly bordered oval articulating faces, equally concave, with rounded margins; the greatest breadth on the anterior face being 3·85 inches; height, 3·10; length, 2·30. The smallest specimen has a breadth of 1·60 inches; height, 1·30; length, 1·26. The neural canal is wide, very little contracted in the middle; the sides are impressed, the base pierced by two foramina situated in depression, which separate more and more as we proceed from the head. The neurapophyses, which are incomplete, rose to about twice and a half the height of the body of the vertebra; the basal processes were short, broad, plane, and directed downward.

The length of the smallest (say 3rd) vertebra is equal to 1·5 inches; of the largest (say 28th), 2·15.

There appear no dorsals or lumbars in either of these sets of vertebræ; there may have been thirty of them.

Nine very distinct caudals appear in the collection from Baldon. Eight of these are consecutive. They occupy a length of 16·9 inches; the most forward four occupy 9·0, and the latter four 7·9, the reduction of thickness being regular. The breadth of the anterior face of the longest of the eight is 3·9 inches, of the smallest 3·1. The separate vertebra (23rd) has a breadth of 2.0 inches.

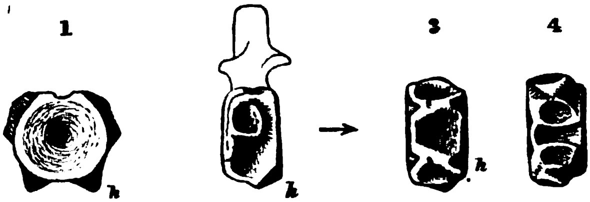

Diagram CLXXII. Caudal vertebra of Plesiosaurus validus.
1. In front. 2. On the left side. 3. Below. 4. Above.

The length of the largest (say 5th caudal) is 2·3 inches; of the smallest known (say 23rd), 1·5. The height of the largest is 3·25 inches; of the smallest (23rd), 1·9.

Counting from the largest to the smallest, we have 1 + interval 6, + 1 + interval 10, + 1, = 19, and beyond this interval 11, making in all 30. To this we must add say 4, for anterior caudals not recovered; the total equals 34, a probable number.

These caudal vertebræ are much alike through the whole series; all having biconcave faces, neatly bordered; broad striated neural canal; prominent lateral processes, and very large and conspicuous separate hæmal cicatrices on the posterior edge. Parts of the neural and lateral processes are sometimes found attached, the hæmapophyses never. The outline, marked by six bases of as many processes, is very remarkable, especially in the smaller bones, which may well be called hexagonal, the height nearly equalling the breadth; while in the earlier vertebræ the faces are oval and broader than high.

The length of the skeleton would appear, allowing for cartilage, to be about 17·0 feet: viz. head, 1 foot 6 inches; neck, 4 feet 8 inches; back, 5 feet 5 inches; tail, 5 feet 5 inches.

PLESIOSAURUS ELLIPSOSPONDYLUS. *Owen.*

The Oxford collection contains a series of nine cervicals from different individuals, and three anterior dorsals. All have transversely elliptical, biconcave articulating faces, with pitted centres; the length is so much less than the height as to ally them to the brachyspondylus species already described. The sides of the cervicals are marked by strong prominent cicatrices; the interforaminal space below is convex, the surface furrowed.

The largest is 4·00 inches in breadth, 3·30 high, and 2·55 long. On an average of all the specimens, the proportions are—length = 100, breadth = 158, height = 130.

PLESIOSAURUS PLICATUS. *Phil.*

Specimens belonging to two distinct but allied species appear under this name in the Oxford Museum. Of the first, the cervical and beginning of the dorsal region are well illustrated in a continuous series of eight vertebræ from Shotover. The cervical vertebræ, confining this term to such as have the rib process supported on the body, and quite separate from the neurapophysis, are, in all, eight in number, five of which belonged to the same individual, and are consecutive. Their places may be (probably) marked as 15, 16–19–22, 23, 24, 25, 26, 27, 28; then follows next in order a vertebra of a somewhat different figure, which may better be called anterior dorsal: only the last three had the diapophyses ossified to the body.

Taken in order from the head, the 15th has a length of 2·5 inches, a breadth of 2·8, and a height of 2·1, measured on the anterior face to the canal, which is broad, biforaminated, and somewhat excavated in the middle; in the 25th the measures are—length, 2·85 inches; breadth, 3·8; height, 2·7: and in the anterior dorsal the length is 2·90, breadth 3·45, height 2·8.

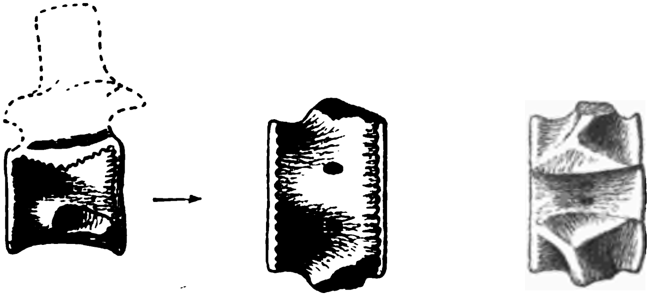

Diagram CLXXIII. Plesiosaurus plicatus.

1. Seen on the left side. 2. Seen beneath. 3. Seen above.

Thus viewed as to proportions, the 15th has length 100, breadth 112, height 84; the 28th has length 100, breadth 133, height 94; and the anterior dorsal has length 100, breadth 119, height 96.

The faces of all these vertebræ are equally, but very slightly, concave; the sides are deeply impressed; the base somewhat convex along the middle, with two large rather depressed approximate foramina, the processes attached by long oval cicatrices, which in the smaller vertebræ are nearly central, but farther along the column occupy a posterior position.

Another series of vertebræ, smaller than those last mentioned, though differing a little in some particulars, must be placed very near to them in a natural series. These are three in number, posterior cervicals just passing into dorsals.

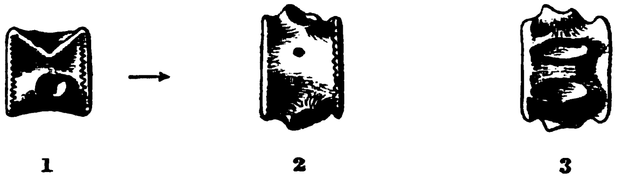

Diagram CLXXIV. Plesiosaurus allied to P. plicatus.
1. Seen on left side. 2. Seen below. 3. Seen above.

PLESIOSAURUS INFRAPLANUS. n. s.

There is yet another form of cervical vertebræ from Shotover, Stanford, and Brill, longer, rather more depressed, and with the lower face flattened between the approximated foramina, by which it differs from P. carinatus. The lateral cicatrices are deep, and placed in the middle of the length. A specimen from Stanford is longer in proportion, and rather more depressed.

Length of a specimen from Brill, 1·79 inches; breadth, 2·03; height, 1·82: or, in proportions, length, 100; breadth, 113; height, 101.

PLESIOSAURUS CARINATUS. n. s.

A small species with remarkably neat, well-defined vertebræ, cervical, dorsal, and lumbar, comes from Quainton in Buckinghamshire, probably, but not certainly, out of the Portland rock. The bone is dense and fine-grained.

Cervicals.—The articulating faces elliptical, plane, pitted in the centre; the foramina on the lower face approximate, with a prominent narrow ridge between them.

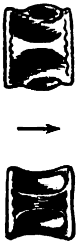

Diagram CLXXV. Plesiosaurus carinatus. Scale one-fifth of nature. Cervical vertebra, seen from below (upper figure), and from above (lower figure).

Length, 1·63 inches; breadth, 1·95; height, 1·60: or, length, 100; breadth, 120; height, 98.

In the anterior dorsals the interforaminal space remains ridged; they are shorter than the cervicals.

Length, 1·45 inches; breadth, 2·00; height, 1·64.

In the dorsals the interforaminal ridge is gradually lost.

Length, 1·40 inches; breadth, 1·80; height, 1·60.

One lumbar vertebra is in the collection.

PLESIOSAURUS HEXAGONALIS. n. s. *Phil.*

A small caudal vertebra from the Cowley clay pits, of somewhat remarkable figure, deserves mention for its almost hexahedral shape, the broad semicylindrical neural canal making one side. The articulating faces are equally concave, much wider than high; there are two medial and two lateral foramina, and the cicatrices for the

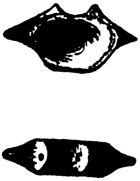

Diagram CLXXVI. Caudal of a Plesiosaur. Scale one-fifth of nature.

hæmal spines are confined to the posterior edge. The neural spine can only have been small.

The length being 0·8 inch, the breadth of the articular face is 1·8; the height to the canal, 1·25; concavity, 0·2. From point to point of the lateral processes, which are firmly anchylosed, is 3·25.

MACROSPONDYLIAN PLESIOSAURI.

A group of plesiosauri, characterized by having vertebræ of greater than the usual length in proportion to breadth, and more or less cylindrical bodies, plane or very slightly concave on the faces, is represented by specimens from Shotover, Garsington, Hatford, Abingdon, and Brill. There are probably two or three species, but not sufficient specimens to furnish good characteristics.

The largest cervical vertebra from Garsington is 3·90 inches long, and about 3·20 in diameter: or, length, 100; diameter, 82.

The dorsal vertebræ are shorter in proportion on an average: length, 100; breadth, 108.

PECTORAL AND PELVIC GIRDLES OF PLESIOSAURIANS.

The diagrams which follow may be useful as shewing the principal forms of the coracoidian and pelvic bones, which appear to belong to the genus plesiosaurus, but cannot with confidence be referred to the respective species already indicated by vertebræ.

Fragments of a pair of ischial bones from Shotover, in general form resembling those of Plesiosaurus Oxoniensis (Diagram CXVI.), were obtained from Shotover previous to 1854, and have been now adjusted. The bones had been subjected to oblique crushing, so as to injure the symmetry more than the drawing represents. The symphysial line is somewhat cariniform, and is straight for a considerable length. The sharp ridges which pass from the outer parts of the articulating ends begin to subside at a distance of twelve inches in their course toward the margins, from which to their origin is 21 inches; the breadth over the condyles being 22·5. The condyles are formed on two slopes inclined to one another 108°, the outer slope being on the largest surface. Measured over the angle, the length of the small condyle is 6·5 inches, the breadth 2·5, probably reduced by crushing.

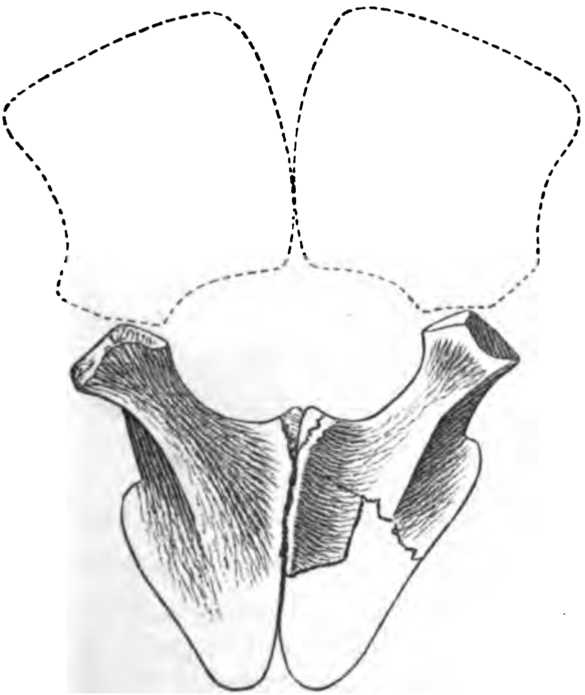

Diagram CLXXVII. Ischial bones of Plesiosaurus.

The pubic bones sketched in connection have been also shewn in Diagram CXLIV. as possibly pleiosaurian, neither appropriation, however, being supported by specimens in apposition.

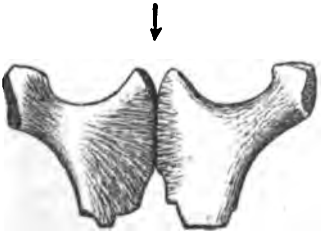

Diagram CLXXVIII. Ischial bones of Plesiosaurus.

A pair of ischial bones from Shotover, considerably vaulted under the broad medial expansion, without oblique ridges, and without keel at the symphysis, which is straight for a considerable length.

Extreme breadth over the condyles, 16·0 inches; length along the middle, 8·25; depth at the symphysis, 1·5. Articular faces double, the two surfaces irregular and inclined to one another about 90°; the inner one 2·5 inches, the outer 3·0 long; depth, 2·25.

A pair of coracoid bones from Shotover, much vaulted under the broad expansion toward the symphysial line, which is much curved, the two bones meeting only for a short length.

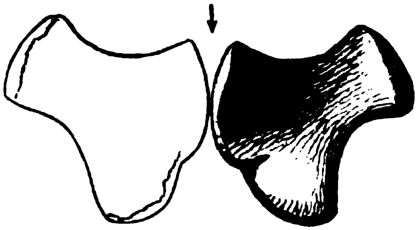

Diagram CLXXIX. Coracoids of Plesiosaurus.

Extreme breadth over the articulating faces of the pair, 22·0 inches; length along the middle, 10·5; depth at the anterior part of the symphysis, 2·0; articular faces formed on a continuous curve, in length 5·0, in depth 2·25.

The anterior part of the symphysis is nearly in a vertical plane; if the bones joined along it, the combined figure would be much altered, by the advance of the articulating heads, and the formation of an obtuse mesial ridge.

A portion of a large ischial bone, formed on the same general plan as that mentioned in connection with Plesiosaurus Oxoniensis (Diagram CXVI.), was placed in Dr. Buckland's Museum, when it came under my management, with the remains of Pleiosaurus brachydeirus from Market-Rasen. It was not labelled, and it is not made certain by examination of the matrix that it came from the same locality as the others. This is represented in Diagram CLXXX.

The strong obtuse ridge which runs from the articular prominence toward the retral margin separates two broad surfaces, which are inclined to one another 125°, so that the space under the ridge is vaulted. The articular face has a sigmoidal curve; it measures in length 5·5 inches, in breadth 4·0.

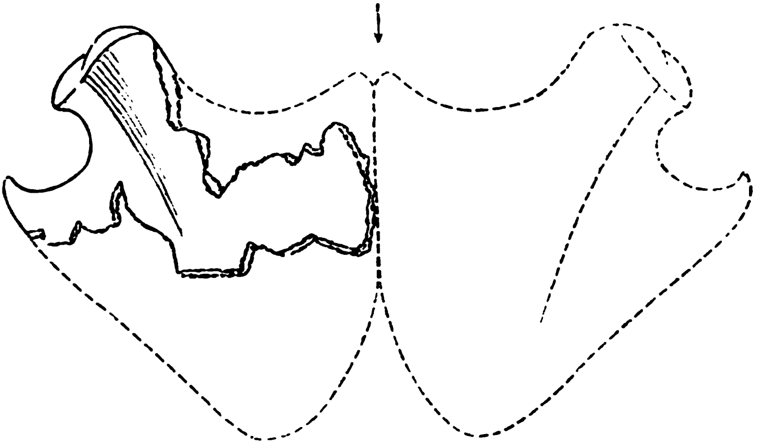

Diagram CLXXX. Portion of ischia of Plesiosaurus.

The united bones represented in the diagrams which follow have been in the Museum many years. They are not marked for locality, but certainly are from the stony or septariate bed of Rasen or Shotover. They have been chipped out of that kind of stone. I suppose them to be coracoids, meeting in a straight short deep symphysis, behind which is a lacuna (*n*). The posterior part is imperfect. I suppose the left-hand figure to exhibit the interior, the right-hand the exterior aspect; (*m*) to be the place of the

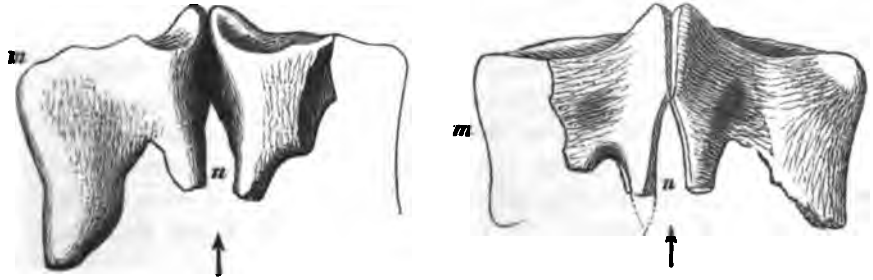

Diagram CLXXXI. Pair of coracoids.
Left-hand figure internal, right-hand figure external view.

articulation much worn away. The other parts are not worn. The anterior face is channeled parallel to the edges, the symphysial line rises externally to a carination, which corresponds to a vaulted interior. If complete, the pair would measure 20 inches across.

TELEOSAURUS ASTHENODEIRUS. *Owen.*

The two cervical vertebræ from the Kimmeridge clay of Shotover, noticed by Professor Owen in his Report on Fossil Reptiles under the above name, are in the Oxford Museum. Other specimens since found, which probably belong to the same species, give the form of the atlas and anterior part of the axis conjoined with it, much resembling the same parts in steneosaurus.

The vertebræ examined by Professor Owen are longer in proportion to their diameter than in other species of this genus. The articulating faces are slightly concave, the anterior least so. The length of the corpus is 2·2 inches; the vertical diameter, 1·6; the transverse diameter, 1·5, according to Owen.

STENEOSAURUS PALPEBROSUS. *Phil.*

The Oxford Museum has for a long time possessed the head of a species of this genus, shewing the upper and lower surfaces, as represented in the diagram which follows, and a considerable part of the lower jaw of the same individual. The specimens were found in the Kimmeridge clay of Shotover Hill. They were briefly described by Professor Owen in his Report on Fossil Reptiles, 1841.

The clay pits of Shotover and Garsington have yielded examples of most of the important bones of this animal, derived from different individuals, and of different ages. The vertebral column is represented by cervical, dorsal, lumbar, sacral, and caudal elements, all decidedly of crocodilian affinity both in form and number.

The arrangement of the pectoral girdle may be understood by

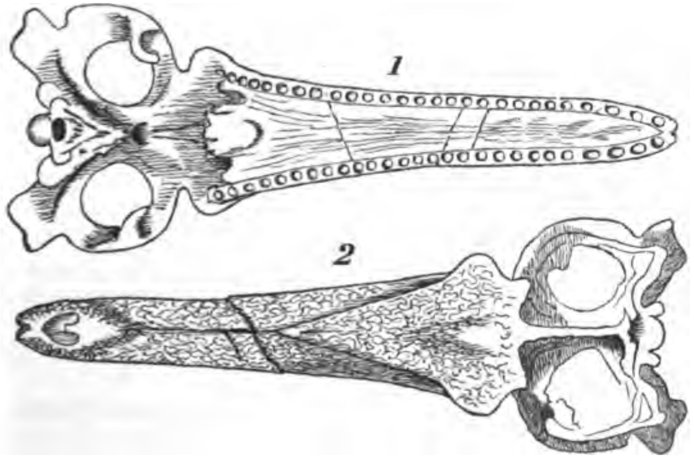

Diagram CLXXXII. Head of Steneosaurus palpebrosus. Scale one-tenth of nature.

1. Under side of the head in the Oxford Museum, shewing the rows of teeth (twenty-seven traceable on one side), the posterior nares, and the lower surface of the frontal and other bones of the head, in relation to the occipital foramen and tubercle and articulating termination of the os quadratum. 2. The upper surface, in which the large temporal lacunæ, separated by a narrow ridge; the frontal bone covering by its lateral extension the orbit, so that the eyes looked out horizontally; before it the two short præorbital canals; the maxillary bones, and the external nasal opening pierced in the intermaxillaries, are all apparent.

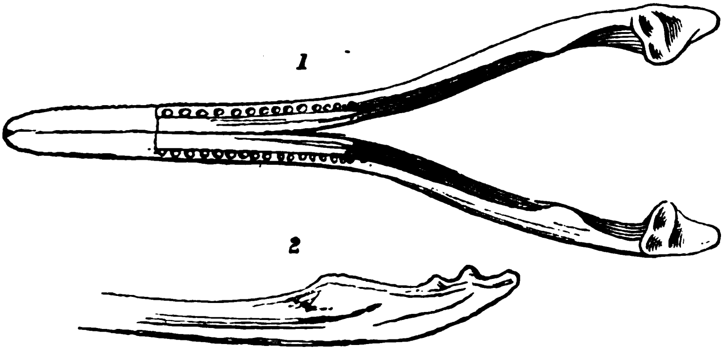

Diagram CLXXXIII. Steneosaurus palpebrosus. Scale one-tenth of nature.

1. Lower jaw, seen above. The anterior part is broken off. 2. The lower jaw, seen sideways, to mark the coronoid process and the projections of the articular bone. The lines below indicate the elements of the bone, but they are obscure.

the following diagram, which reminds us of the crocodilian structure.

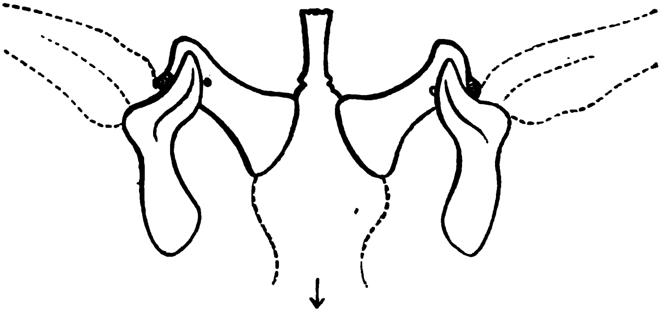

Diagram CLXXXIV. Steneosaurus palpebrosus. Scale one-tenth of nature.

Sketch of the shoulder girdle, seen from above and in front. The parts dotted, representing sternum and humerus, are conjectural.

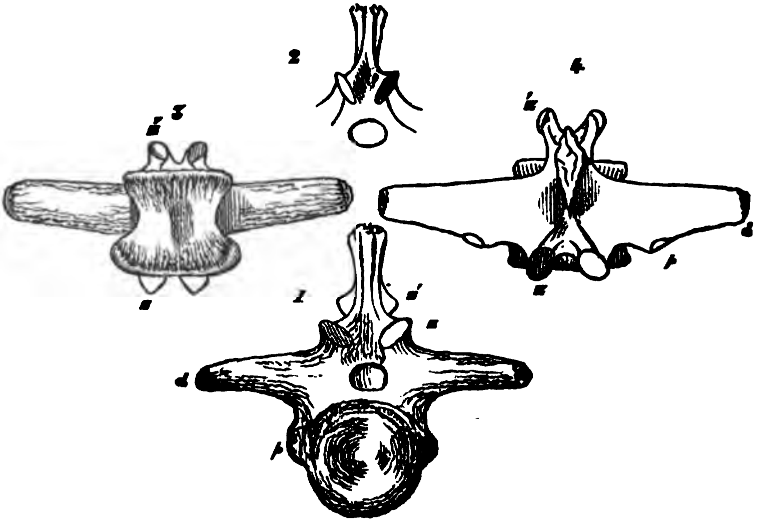

Diagram CLXXXV. Steneosaurus palpebrosus. Scale one-fifth of nature.

1. Anterior face of fourth dorsal vertebra. 2. Posterior face of part of the same. 3. Basal view of the same. 4. View of the upper surface of fifth dorsal vertebra. *z* Anterior; *z'* posterior zygapophysis; *p* and *d* the articulating surfaces of the ribs.

Of the bone represented by figs. 1 and 2 three specimens have come to us with many portions of steneosaurus. It appears to be a humerus, in which still remain traces of a crocodilian type, though the whole is shortened, the proportions are altered, perhaps to a more decidedly aquatic adaptation. The upper part is concave internally, and convex outwardly, and much roughened by tendinous attachment, as is likewise the lower more uniformly convex end, which has two unequal facets somewhat obscurely marked. What appears to represent the deltoid crest is traceable in the upper part.

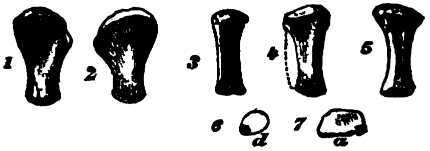

Diagram CLXXXVI. Steneosaurus palpebrosus (?).

1. Humerus (right), seen internally. 2. The same, seen externally. 3. Tibia, right side, seen externally. 4. The same, seen posteriorly. 5. The same, seen anteriorly. 6. Outline of distal condyle (*a*. anterior). 7. Outline of proximal condyle (*a*. anterior).

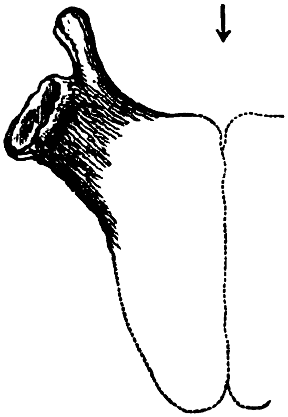

Diagram CLXXXVII. Steneosaurus palpebrosus. Scale one-tenth of nature.

The right ischium, seen from below.

The pelvic girdle is only partially known by the right ischium.

Femur.—This bone, of crocodilian type, but more sigmoidal, more compressed, and with less definite condyles, is 11·4 inches long, 2·1 wide near the proximal, and 1·9 wide near the distal end, and 1·25 where narrowest (two-fifths of the length from the distal end). It is thickest near the upper end, 1·20 inch, and thinnest from the middle toward the distal end, 0·95. The bone is compressed so as to be almost carinated on the upper or forward edge; striated longitudinally and roughly near the proximal end by the attachment of tendons; more finely striated near the distal extremity. The curve of the head of the bone is like that of crocodile, and there is a trochanterial tubercle on the exterior surface, 2·25 inches below the head, matched by another less distinct on the opposite surface.

A tubercular projection on the inner face enlarges the curved area of the head of the bone, and gives to the end a rhomboidal shape. The lower end is very indistinctly marked for condyles, and finishes with a curve, which probably corresponds to the aquatic life of the race. Both extremities appear to have lost portions which perhaps were cartilaginous.

Tibia.—A pair of short strong triquetral bones, the end outline of the head trapezoidal, that of the distal end ovato-acuminate, has been found at Garsington, with bones of steneosaurus. Length, 4·15 inches; breadth, 1·8 at the head, and 1·15 at the lower end; these ends having their surfaces converging at an angle of 20°, and their long axes diverging about 30°. The upper adherence of fibula is distinctly marked. It resembles the tibia of chelonia, and agrees in shortness with Cuvier's notice of the bone at Honfleur. See Diagram CLXXXVI., figs. 3, 4, 5, 6, 7.

STENEOSAURUS GRACILIS. n. s.

The Portland rock has yielded this interesting species of crocodile. Mr. J. W. Mason, a diligent explorer of the geology round Oxford, during his residence in the University noticed a fragment of the animal thrown on the road; afterwards by his labour, and that of my assistant Henry Cowdell, a large spheroidal block of sandstone which had concreted round the bones was carefully broken, and the head, with cervical vertebræ, was recovered. Other parts of the animal may have been included in other such blocks, but none were discovered among those masses which could be examined.

Length of head, if complete, probably 30·0 inches; maximum breadth across parietal region, 8·0; across frontals, in front of the eye, 6·0.

Surface of bone rather smooth. Projection in front of orbit nearly horizontal, with oval outline, protecting foramina which, *in place*, correspond to the nares of enaliosaurs. A narrow parietal ridge between oval temporal fossæ.

Occipital surface pentagonal, nearly vertical, much as in crocodile, but the basi-occipital wider, undulated, perforated for blood-vessels, joined by synostosis to the os quadratum, the articular edge of which

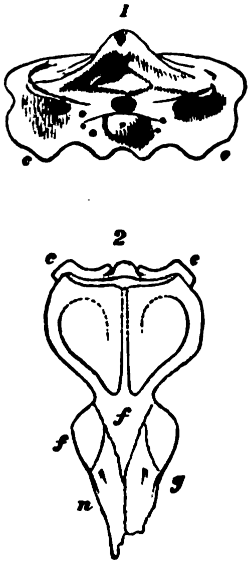

Diagram CLXXXVIII. Steneosaurus gracilis.

1. View of the occipital surface, shewing the foramina in the basi-occipital bone. *c.* The condyles. (This drawing is made to correspond in size with the view in Diagram XLVI. p. 189.) 2. The head, seen from above. Scale one-tenth of nature. *c.* Condyles. *f.* The frontal. *f.* Anterior frontal. *n.* Nasal bones, according to the nomenclature of Cuvier. *g.* The præorbital groove.

is more oblique than in crocodiles. The basi-occipital prominence has no vertical furrow, but a slight mark of central depression. Lateral and supra- occipitals present a concave surface, the laterals ending in a distinct prominence above the tympanic bone.

The temporal fossæ are large and oval, contracted toward the orbits. The frontal bone extends into a long prominence between the nasals, having on each side elongate pre-frontals. At the juncture of the anterior parts of these with the nasals is a deep groove or canal, corresponding in place to the nasal foramina of enaliosaurs (Cuv., Ossemens Foss. Plate VIII. fig. 8 d).

The frontal shews three parts, and was probably composed of five, but the limits are hardly traceable.

The maxillary bone is not known. The under surface of the frontal and pre-frontal bones is scooped in hollows corresponding to the general figure of the bones, which are about half an inch thick. A part of the brain cavity is exposed on the under side of the specimen.

In the lower jaw a thin, nearly vertical plate of bone (the 'surangular') extends from the articulation forward, and rises into a prominent coronoid process, as far in front of the condyle as the articular bone extends backward. The concave articular surface is directed forward and downward. The lower or 'angular' element of the inner jaw is inflected inwards.

The following are some of the dimensions of the head and lower jaw :—

	inches.
Lower jaw. Length from the end of the articular bone to the posterior edge of the articular surface	2·1
Length to the anterior edge	2·9
Length to the crest of the surangular bone	6·0
Height of the jaw at the surangular crest	2·8
Cranium. Extreme breadth over the jugal bones	8·25
Breadth of occipital surface from condyle to condyle	6·75
Extreme height of occipital surface	4·75
Breadth of occipital condyle	1·20
Height of the same	0·80
Diameter of foramen magnum	0·75

Vertebræ.—The axis corresponds in general to that in the crocodile (see Cuv., Ossemens Fossiles, iv. 2), shewing like it a short posterior neural crest, with the zygapophyses plane, oval, and inclined about 160°. In the anterior and lower part is the odontoid bone, separated by a clear suture from the corpus. One styliform process proceeded from the odontoid, and another from the body of the axis immediately behind it.

Two other cervical vertebræ have been observed, both carinated below. Each has two transverse processes, the upper one descending from above the suture, the other running backward from the anterior edge. The body is oval in contour, higher than broad, concave on both faces, most so on the hinder surface; one is marked with a central pit.

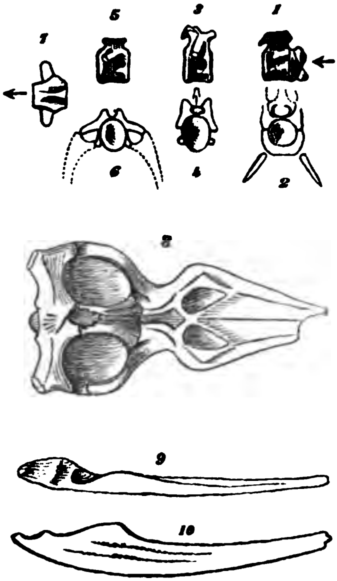

Diagram CLXXXIX. Steneosaurus gracilis. Scale one-tenth of nature.

1. Lateral view of atlas and axis vertebra, conjoined by bony suture. The basal and lateral elements of the atlas (of the superior element is only a trace), and what represents the odontoid process, make an anterior ring which is united by bony suture to the true axis. To the former ring are attached the first styliform processes, to the true axis the second. 2. The front view of the bone; the central part is not usually regarded as a part of the atlas, but is united with it, and forms the concavity. The styliform processes are shewn. 3. A cervical vertebra, seen laterally. 4. The same, seen in front. 5. Another vertebra of the same general type, probably the first dorsal, seen laterally. 6. The same, seen in front, with the probable ribs. 7. The same, seen from below, to shew the carination. 8. The lower surface of the head, as seen in the specimen from Shotover. 9. Lower jaw, seen from above. 10. Lower jaw, seen from the outside.

Length, 1·5 inch; height, 1·5; breadth, 1·3—on the average of the two vertebræ.

One anterior dorsal has occurred, carinated beneath; the body higher than broad; concave on both faces, most concave behind. The upper transverse process runs out from above the suture to about three-fourths of the breadth of the vertebra; its direction is downward and a little backward. The parapophysis rises free from near the anterior edge; it is depressed with an oval section.

Interval between the rib articulations, 1·0 inch; length of the vertebra, 1·5; height of the same, 1·45; breadth of the same, 1·25.

STENEOSAURUS LONGIROSTRIS. *Cuv.*

Among other saurian remains of interest found in the Kimmeridge clay are jaws and teeth which seem to be of the same kind as the long-beaked gavial of Honfleur, described by Cuvier. A specimen in the Oxford Museum shews a portion of the lower jaw, with teeth *in situ*, one of which is represented in the Diagram below.

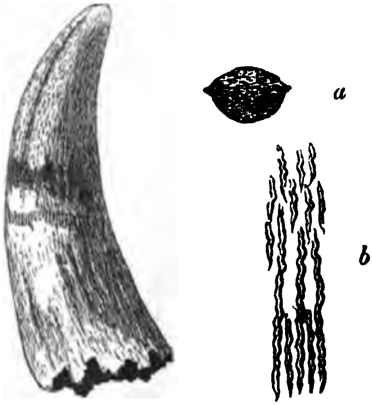

Diagram CXC. Steneosaurus longirostris.

The tooth here represented on its exterior face is of the usual size along the sides of the jaw. Two distinct carinæ appear, toward which, in a slight degree, the minute rugulosities of the surface converge. On the concave part of the surface these become fine distinct undulated striæ. *b*. The base widens much and becomes hollow, indicating the mode of replacement to have been axial, as in crocodiles. The cross section shews the carinæ to separate rather unequal portions of the tooth, *a*. Dentine close, firm, and dark. Enamel thin.

The portion of jaw referred to is the symphysial part, and seems nearly complete at the anterior end. It is 20 inches long; the breadth is 3½. Thirteen teeth on one side, fourteen on the other.

DAKOSAURUS.

This title, given by Quenstedt to some teeth of the upper Jurassic series, has been applied by Mr. J. W. Mason to specimens found in the clay of Shotover. The distinctness of these teeth from others which have been ascribed to steneosaurus is doubtful.

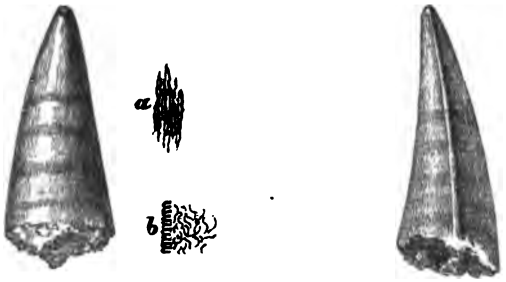

Diagram CXCI. Dakosaurus.

Conical slightly-arched tooth with carinated and crenulated edges (*b*), and a finely-wrinkled surface (*a*). Across the tooth run some faint dark bands. This corresponds to Dakosaurus maximus of Quenstedt (Jura, Plate XCVII. fig. 11).

These teeth appear to be closely allied to those of steneosaurus. The crenulation is seldom so regular as represented in *b*.

There is a different set of teeth which seem more allied to megalosaurus, being very compressed, with a faintly striated surface, but without any observed crenulation on the edges. They correspond with others called dakosaurus by Quenstedt (Jura, Plate XCVII. figs. 9, 10).

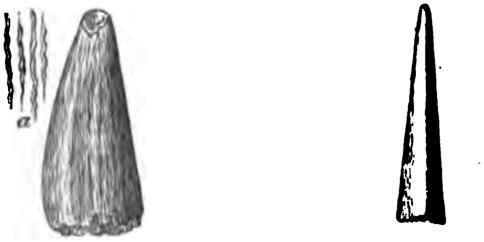

Diagram CXCII. Reptilian teeth, from the Kimmeridge clay of Shotover.

The left-hand figure shews the broad outer surface, and at *a* the raised and undulated striæ; the right-hand figure shews the same edgeways.

CETEOSAURUS LONGUS.

A caudal vertebra from the Portland stone at Garsington, near Oxford; length, 7·0 inches; transverse diameter, 7·9; vertical diameter, 6·0. Both articular faces slightly concave; body slightly compressed laterally, so as in the middle to give a subquadrate vertical section, with the angles slightly rounded; the expanded articular ends subcircular.

A fractured dorsal or lumbar vertebra, from the same locality, with transverse processes extending obliquely backwards from the upper part of the sides of the body, measures *one foot* across the nearly flat articular surface.

A caudal of the same species, from the Portland stone at Thame, measures 7·4 inches in length; 6·6 in transverse diameter; and 7·8 in vertical diameter. The under surface is concave lengthways, and it is nearly flat from side to side; it is perforated by many large vascular canals.

A third caudal is somewhat shorter, but not less than 8 inches in height.

In all these vertebræ the neurapophyses are anchylosed to the centrum, and have a smaller antero-posterior extent at their base than the centrum.

These notices of specimens in the Bucklandian Museum are taken from Professor Owen's report to the British Association, 1841. We possess at present only two of them, the first and third mentioned.

It is by no means certain that they are congeneric with Ceteosaurus Oxoniensis. Had dorsal vertebræ been obtained shewing the very deep lateral depression (Diagrams LXXXVII., LXXXVIII.) which in some crushed examples seems almost to become a transverse perforation under the neural canal, or had the neuro-spine been preserved, with a clavate head, we might have boldly ranked these Portland fossils with those of the Bath oolite. But the caudal vertebræ in our possession do not furnish sufficient evidence.

MEGALOSAURUS BUCKLANDI.

The reason for admitting this great reptile into the catalogue of fossils of this age, is the discovery of three metatarsal bones, in their natural apposition, in the clay exposed in the Great Western Railway near Swindon. No other part of the animal having come under our inspection, it is only on the evidence of these bones that the species can be recognized.

But this evidence is very clear. Each of the three bones is identified with specimens from Stonesfield and Enstone (Enslow?) in respect of the distal extremities, and the whole bone can be compared in the case of the middle metatarsal. Neither along the external or internal bones are such appearances to be seen as to indicate any other than the three toes, which also are the only ones recognized among the Stonesfield fossils. (See Diagram LXVIII. p. 215.)

We have now reached the point in the scale of geological time when, from this part of the earth's surface, the great forms of reptilian life appear to have departed. Elsewhere the 'age of reptiles' was indeed extended to more recent dates, in the wealden of Sussex, and the cretaceous strata of Kent and Cambridge; but there also the series came to an end. Ichthyosaur and plesiosaur, iguanodon and pterodactyl, vanished with many other forms of ancient life; and true crocodiles swam in the estuary of the Thames, over the remains of teleosaurs and steneosaurs, buried 'fathoms deep' in strata of the mesozoic sea.

In the cliffs of Kimmeridge, Colonel Mansel has found, and Mr. Hulke is examining, animals allied to the pleïosaurian, plesiosaurian, and steneosaurian fossils here noticed. In particular a gavialian crocodile approaching the type here called steneosaurus[e]. These researches will furnish the means of a most interesting comparison of the fossil reptiles of one zone of life in two most productive localities.

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[e] Geol. Proc. 1869.

CHAPTER XIV.

RETROSPECT OF THE OOLITIC SYSTEM.

THE circumstances under which the great tripartite system of oolitic deposits took place are sufficiently varied in detail, and often enough repeated in successions of similar events, to encourage an attempt to treat the whole with reference to some general laws which may be accepted as at least approximately true. The physical conditions of deposit having been in this manner considered, the series of oceanic life may become the subject of further generalization.

First, then, we remark in the whole oolitic system, from the base of the lias to the top of the Portland rock, no remarkable even local derangement of the parallelism of deposits, so that violent movements during the whole long period under review, though they may have happened elsewhere, could have had no special influence in this comparatively tranquil sea-basin. Yet that both limited upward, and especially extensive and continued downward, movement occurred will be manifest on considering certain phænomena. That dry land subject to inundations was at no great distance during the whole period, is evident by the not infrequent occurrence of drift-wood in all parts of the series of strata; but the actual inflow of rivers is not to be put in clear evidence, though lagoon laminations or estuarine accumulations may be inferred both at the base of the lias and the top of the Portland, as well as in the Stonesfield, Collyweston, and Poulton slates.

A conglomerate can hardly be quoted in the whole of this oolitic series of the midland; only rarely any mark of approach to the ancient shore, though one such has occurred to me in the brow of a hill at the edge of the oolite on the Chipping-Norton road above Banbury. We have therefore sea deposits under ordinary quiet conditions, probably not far from shore, and in some cases even littoral, the materials being derived from wasting lands and organic accumulations.

These materials are principally calcareous, arenaceous, and argillaceous, with admixture or impregnation of iron oxides, carbonates, and sulphides.

The three principal mineral elements are arranged in ternary groups, so that in many places the order runs thus, downwards[a] :—

Calcareous	Portland oolite.
Arenaceous	Portland sand.
Argillaceous	Kimmeridge clay.
Calcareous	Coralline oolite.
Arenaceous	Calcareous grit.
Argillaceous	Oxford clay.
Calcareous	Cornbrash.
Arenaceous	Hinton sand.
Argillaceous	Bradford clay and Forest marble.
Calcareous	Great oolite.
Arenaceous	Stonesfield sands.
Argillaceous	Fuller's-earth.
Calcareous	Inferior oolite.
Arenaceous	Midford sands.
Argillaceous	Upper lias.

The remarkable ternary order here so often repeated is found again in the sections of carboniferous strata which include the three terms in Yorkshire. As many as five of these combinations can sometimes be found in the Yoredale series alone[b]. It is repeated in the cretaceous series—chalk, greensand, and gault—and the explanation has been furnished in a discussion of the Silurian Strata[c], on the simple and sure basis of interrupted depression of the sea-bed. (See pp. 92, 93 of this volume.)

In the cases before us the liassic sea-bed first receives only the finest sediments which can fall in deep water; by degrees these sediments accumulate so as to bring the sea-bed near enough to the surface for the drift and settlement of the fine sand of Midford and Frocester: on this sandbank flourish colonies of coral and shells, and constitute the basis of the Inferior oolite. Depression follows; the deposit again becomes argillaceous 'fuller's-earth;' shallow water succeeds, and the Stonesfield banks of sand and shells appear, followed by the Great oolite rock. Less distinctly the same things occur and recur; and the cornbrash ends this series.

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[a] Thinner sands occur in some places above the Portland and Coralline oolites.

[b] See Illustrations of the Geology of Yorkshire, vol. ii.

[c] See Memoirs of the Geological Survey, vol. ii.

Next we have a long depression marked by 600 feet of Oxford clay, followed by the fine sandbank of calcareous grit, on which corals and oysters and many forms of life grew in profusion.

Again the same things are repeated for the Kimmeridge clay, Portland sands, and Portland oolite.

It deserves remark that the three orders of deposits, clays, sands, limestones, are so much alike in the several groups as to be in fact hardly distinguishable by hand specimens; they seem all to have been derived from similar sources—from neighbouring shores and lands, with no importations from afar. The oolitic limestones, however, offer some peculiarities worthy of consideration.

Oolite, the title of a large series of the calcareous rocks (included in this section), is properly applied to those portions which contain spherical or ellipsoidal grains, of nearly equal magnitude, cohering together or cemented by intervening matter. They are usually small, as the roe of ordinary fishes; whence the synonym of roe-stone (German rogenstein); but sometimes large as peas, and then called pisolite. In a general view we may include, for comparison, the spherical dolomitic concretions of Sunderland. Each of the spherical grains is formed of more or less distinct concentric sheaths crossed by radiating fibres. The corresponding parts in the dolomite alluded to are of decidedly crystalline structure. It is possible that this may be true of some oolites, but in general the small masses appear to have been gathered by attraction out of calcareous mud round nuclei of previously solidified matter—minute fragments of coral, echinida, crinoids, foraminifera, and various shells—or, in some cases, round grains of sand. Finally, the oolitic structure is exhibited in a large, rude, and irregular form in the pea-grit, of the Inferior Bath oolite, and the pisolite of the Oxford series.

We may distinguish several conditions of the oolitic aggregates.

The oolites of Ketton and Painswick are remarkable for containing in large proportion beds of purely oolitic texture, the grains of small and very equal size, cohering by their surfaces without intervening cement.

The Bath oolite contains similar beds of 'fine freestone,' and in these it is not uncommon to find the spherules hollow within, so that the stone is very light and very absorbent of water.

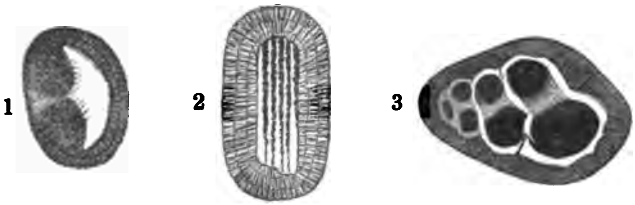

Diagram CXCIII. Magnified sections of grains of oolite, shewing aggregation round an organic nucleus. 1. A grain gathered round a finger-joint of a crinoid; 2. round a small spine of Cidaris; 3. round a minute foraminifer.

The oolite of Ancaster in Lincolnshire has beds in which the grains are immersed in a matrix of clear calcite, whose glistening faces and cleavage lines are evident on fracture. This crystalline network may often be detected in parts of those rocks which are not obviously oolitic, and indeed are somewhat arenaceous.

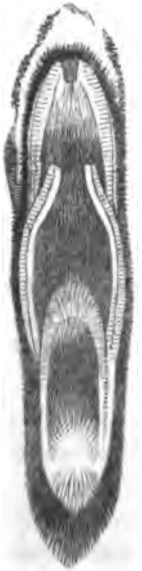

Diagram CXCIV. Magnified view of a discoid foraminifer, with a thin accretion of calcareous matter, constituting an oolitic grain.

The Forest marble and Stonesfield beds give abundant examples of oolitic grains scattered or forming layers in shelly beds, and these when cut through display a great variety of nuclei, the grains being somewhat irregular in size and shape.

Again, we have near Oxford a variety of appearances caused by the dispersion of comparatively few grains of oolite through the substance of a compact calcareous rock; and, as at Dundry, near Bristol, these grains may be ferruginous.

Thus we are led to the case of Rosedale in Yorkshire, where the thick valuable and partly magnetic dark ironstone is really an oolite of even texture, composed of sesquisilicate and carbonate of iron, with little foreign admixture. It appears to have few shells in its substance, just as the pure massive oolites of Bath and Ketton yield few organic remains, while the laminated and other less oolitic portions of adjacent rock are filled with them.

When, however, we speak of Great oolite, Inferior oolite, and the like, it is only in a general way that we refer to the mineral constitution of those rocks. Oolite is a characteristic form of some of the component strata, but the structure is not confined to them.

The colour of oolite as seen in ordinary open quarries is usually a pale yellow, sometimes a little embrowned or reddened by carbonate of iron. But the same stone obtained from a considerable depth in the earth, and especially under a covering of clay, is usually blue. The bleaching of the open-air stone is often only external, the central parts of a massive block retaining still the original blue tint. The explanation is found in the action of water, which by bathing the external parts of the stone alters the condition of the iron. This has usually been regarded as originally protoxide, but Mr. Church has found the blue centres of Forest marble near Cirencester to contain bisulphide of iron. In some cases sesquioxide of iron occurs in the blue parts.

The formation of the oolitic grains seems to have followed on the accumulation of calcareous mud; in some cases the whole of this mud has become oolitic, in others segregations of distant sphericles took place. In some examples carbonate of iron has the same structure and the same variations, as if what had been at first a carbonate of lime had been transformed to ironstone by the substitution of iron oxide for lime, as Sorby has observed.

The iron-bands are of various aspect. Where fully developed, as in Northamptonshire, they exhibit near the surface the rugged appearance of half-empty iron boxes, laminated nodules, and continuous beds. In thinner masses, as at Worton, curved and concentrically-laminated portions of much richness exhibit oolitic grains. Sometimes merely irregular patches diversify the ordinary oolite, as in the upper beds of Great oolite at Stow-Nine-Churches.

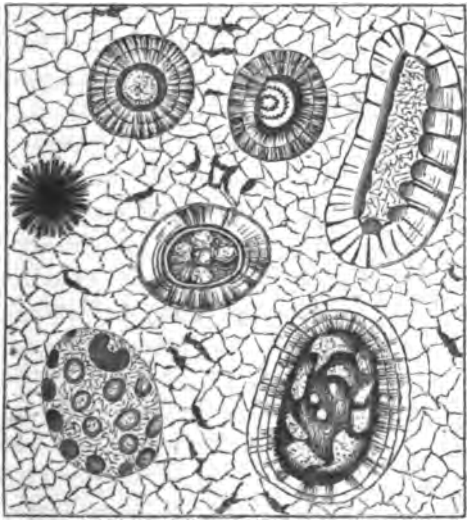

Diagram CXCV. Grains of Bath oolite, collected round various objects, all immersed in a paste of calcite.

The sandy parts of the series are always found to be in very fine grain—'sea-sand,' as the workmen call it—and being often the channel of subterranean water, it is 'quicksand,' as the engineers found on the North-Western Railway. A crystalline web of calcite is occasionally found to unite the grains into a hard rock.

The clays of the Bath oolitic series are usually blue, and fit for making bricks; those which divide the middle parts of the Great oolite and Inferior oolite are rather marls than clays. The clays above the Great oolite have an estuarine character, at least in part, and contain often jet and rarely cyrenæ. Septaria are not usually found in any of these clays.

The aggregation of these calcareous, arenaceous, argillaceous, and ferruginous elements into laminæ and beds is in some respects peculiar. The 'ragstones,' often found toward the top and toward the bottom of thick oolite, themselves shelly or oolitic in texture, are frequently formed in extensive horizontal beds composed of laminæ or smaller beds inclined about 30°. In Gloucestershire the lower rags of the Great oolite have this character extensively. It is due to watery movement at small depths. When this movement has drifted matter very uniformly in one direction, the result is a bed with laminæ, all parallel but inclined: where the current changed or admitted of eddies, the deposits vary accordingly. These phænomena, called 'false-bedding,' are very instructive as to the conditions under which the oolitic rocks were accumulated. Very similar deposits happen at present where affluents enter lakes and bring or disperse gravelly and sandy materials on the bed. Thus have been formed some deltas, especially the lower gravelly parts. Such deposits are now in progress in the Lake of Geneva, where the Rhone enters it, and they may be seen occasionally produced in transitory forms of small extent on our sea coasts.

Veins of calcite, regular or quite irregularly branched, appear in most parts of the 'freestone' beds, as at Taynton, and somewhat impede the action of the toothed saw by which this stone is neatly and cheaply cut. Calcite occurs also freely crystallized in joints of the rock and in cavities from which shells or corals have been dissolved away; and this substance often, with quartz and oxide of iron more rarely, are found lining cavities in the shells of cephalopoda. Sulphate of strontian, finely crystallized, said to have been found in a vein near Handborough Junction, was placed in my hands in 1854.

The changes of organic life in such a basin of the sea, unaffected by great disturbances, may be considered with reference to causes known to be influential in modern nature; as, for instance, depth of water, distance from shore, and quality of 'ground,' or sea-bottom; and in relation to time, which hardly enters as an element into modern zoology.

It happens in the cases before us that quality of ground and depth of water go pretty closely together with distance from shore; greater depth and removal from shore with the clays; lesser depth, probably nearer approach to the shore, with the sands: the least depth as a rule may be ascribed to the limestones, especially those parts of them which resemble or even consist of shell and coral banks.

If then, in comparing clays of the lias with those of the Oxford and Kimmeridge stages, or the sands of Midford, Studley, and

Shotover, or the oolites of Cheltenham, Cumnor, and Swindon, we observe in each of the three examples characteristic differences in the organic forms, it will be reasonable to refer these, at least in the first instance, to the difference of the time; in other words, the forms have changed with the lapse of time.

That we do find characteristic specific differences is matter of universal consent. Thus, to take the clays, we have in the three great deposits of this nature—

Ostrea deltoidea.	Ammonites biplex	Kimmeridge clay.
Gryphæa dilatata.	„ Duncani	Oxford clay.
„ incurva.	„ bifrons	Lias.

And, to take the limestones, we have—

Trigonia gibbosa.	Ammonites gigas	Portland oolite.
„ clavellata.	„ perarmatus	Coralline oolite.
„ striata.	„ Parkinsoni	Inferior oolite.

(The sands have but a restricted fauna, and contain few species not found in the limestones and clays.)

Many species and many genera of fossil marine animals appear to have their beginning, progress, and end discoverable by observation; and these phases of each life are often completed in one great system of strata, a species often lasting through 50, 100, or more feet of deposits, a genus through 1000 or more feet. Thus Terebratula fimbria, in the middle part of the Inferior oolite, and T. coarctata, in the Bradford clay and upper layers of Bath oolite, are almost limited to those narrow zones, while the genus which includes them began its long career before the oolitic system, and is still in existence. In Plates V. and VI. certain zones of characteristic species of cephalopods are marked on the scale of the oolitic and cretaceous systems. A very large proportion of the genera of marine oolitic invertebrata is found fully represented in the Bath group: the number diminishes each way, there being fewer in the lias below, and fewer in the oolites above. Hence arises the idea of the oolitic fauna having its capital, so to speak, in the Bath oolites. Originating in the lowest lias, it attained its maximum of extension in the zone of those oolites, and then declined to extinction in the uppermost layers.

The same idea presents itself to the student of palæozoic life, especially the large Cambro-Silurian series, which, beginning with a few scattered species, grows to great richness in the Bala and

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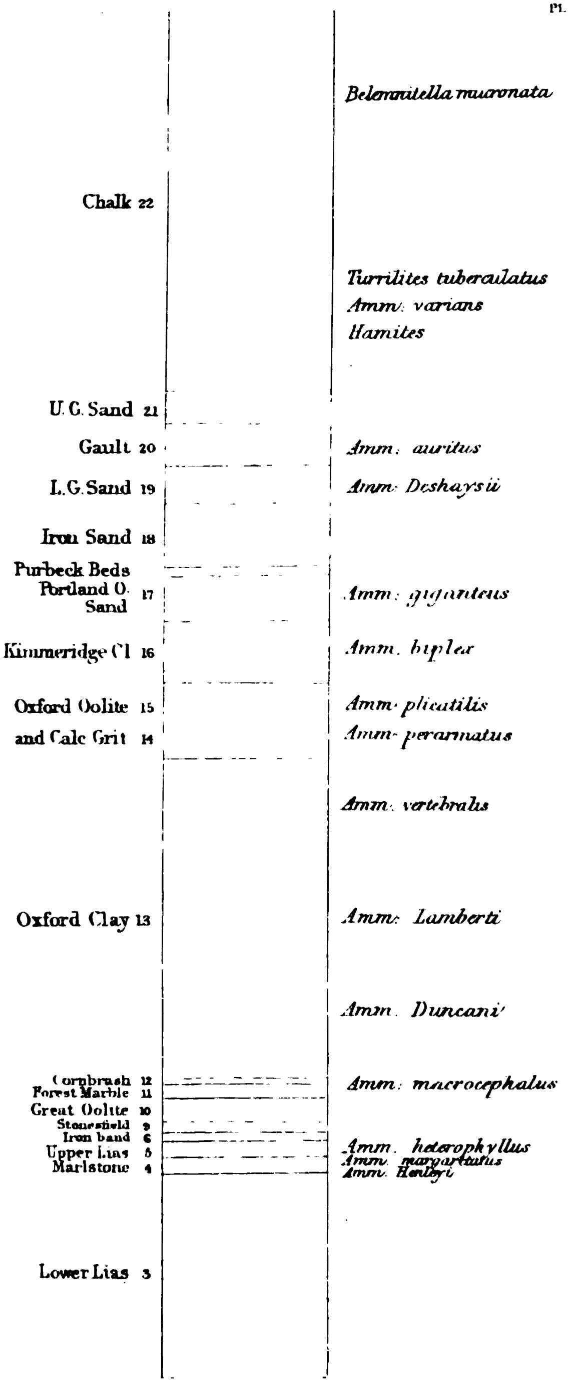
Wenlock groups, and then 'dies out' in the uppermost Ludlow rocks. The Devonian and carboniferous groups give another example of the same order; in fact, every great natural system of strata which includes littoral, shallow, and deep sea deposits, offers similar results in each limited natural district—a beginning, a progress, an end, of many though not all the forms.

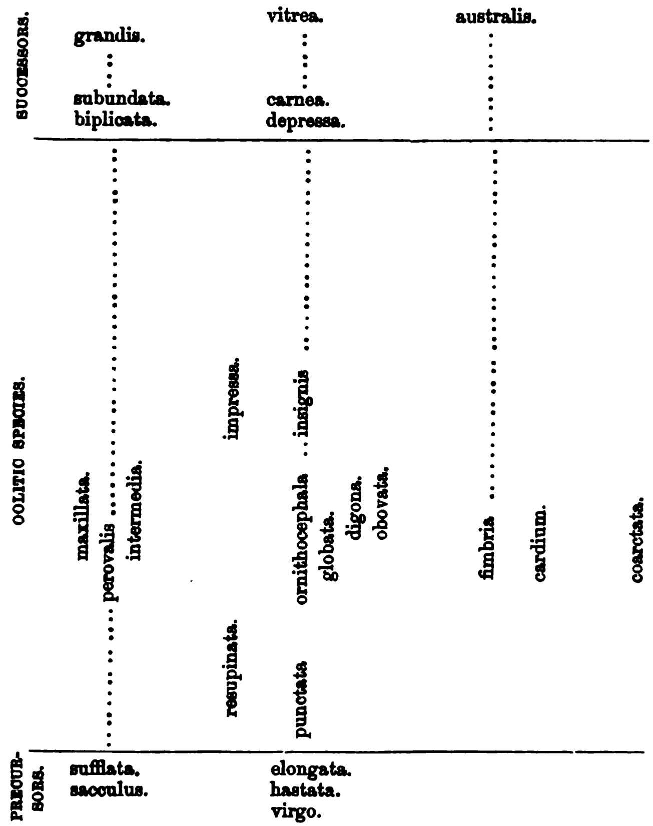
The result here presented is derived from studying limited natural districts; when many separate districts are combined in a general view, the conclusion is somewhat modified. Thus the poor English series of poikilitic rocks loses in a general argument its character of sterility and separation, and acquires many liassic affinities in the muschelkalk, and some Permian alliances in the lower sandstones. By this means the 'beginning' of the great liassic and oolitic fauna is carried in Europe to a somewhat earlier point of geological time than in England; when we reach that point its main features end in a reduced though considerable number of forms for which no ancestors can be found, mixed with others which seem to claim an earlier pedigree. Out of observations of this kind, on the one hand, indicating original *diversities* the idea has arisen of several successive and separate systems of living beings adapted to successive conditions of the globe; on the other, the recurring or continued *agreements* seemed to be best explained by 'descent with modification' from a common ancestry. These general ideas can never be absent from the mind of the geological student, and have indeed become subjects of popular discussion, often with a very inadequate estimation of the phænomena to be explained.

In a limited sea-basin, in one system of strata, deposited in similar conditions, with continuous life, the distinctive forms of the several genera ranged in order of time furnish evidence in the most complete form we are likely ever to obtain it, whereby the hypotheses referred to can be examined, or rather one of them, that of 'descent with modification.' In the Oxford district of oolites we have such conditions, and may select as many examples as we please of 'continued forms' of life. Choosing in preference sedentary rather than erratic races, we may limit ourselves to a few examples of brachiopoda, monomyaria, and dimyaria, and place well-known species of each in the order of time—all the genera being still existent.

Section of Mesozoic Strata in Oxfordshire.

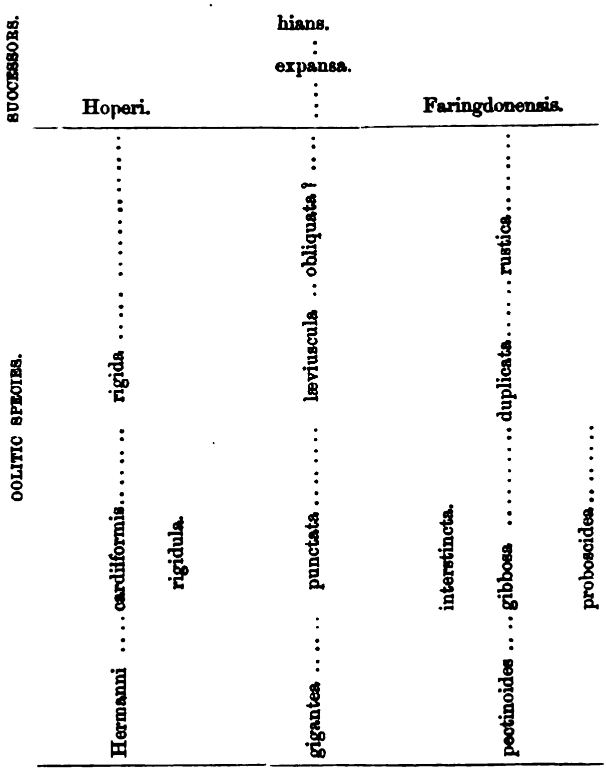


AFFINITIES OF OOLITIC TEREBRATULÆ.



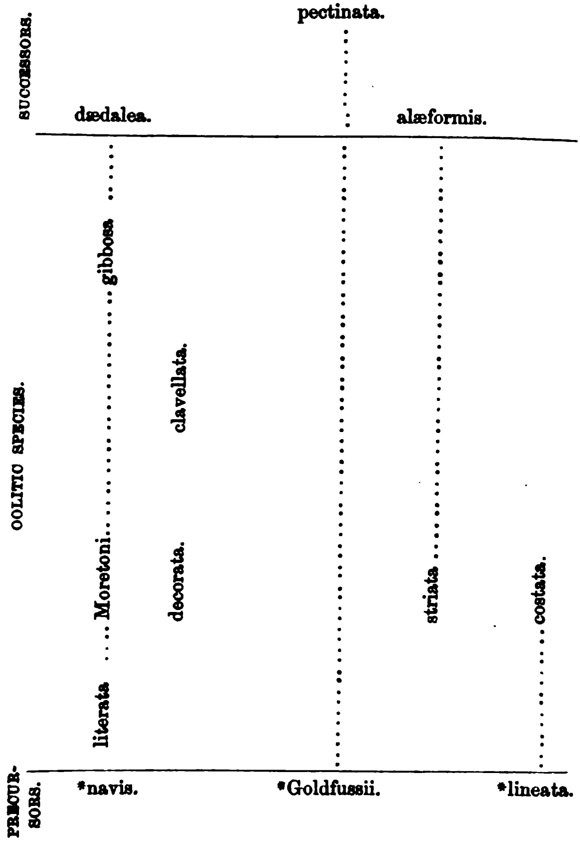
The 'main line' of terebratula, traced here from T. virgo in the Devonian rocks, seems to experience a great gap in the upper oolite group, but resumes its course in the cretaceous strata, and reaches the modern sea in T. vitrea. The parallel line from T. sacculus to T. grandis, and the limited occurrences related to T. obovata, might be fairly joined into the main stream as ordinary modifications by descent; but T. fimbria recurring as to type in T. australis, T. cardium and T. coarctata, sporadic terms of short period, require additional suppositions.

AFFINITIES OF OOLITIC LIMÆ.



Three, or perhaps four, distinguishable fossil races are included in this Table, originating in the sharply-ridged Lima pectinoides, the smoothly-polished L. gigantea, the ribbed L. Hermanni, and the tubercled L. proboscidea. They are frequent in the lias and oolites, and the recent species, though not very numerous, present structural characters which bring them into relationship with the older members of the family. Original differences have had long periods of successive representation.

AFFINITIES OF OOLITIC TRIGONIÆ.



Trigoniæ, transversely-ribbed or ornamented with transverse rows of tubercles, mark two conspicuous fossil groups, neither of them paralleled in modern nature. The modern species is radiated from the beak, and so is T. Goldfussii of Alberti, found in the muschelkalk. Each of the groups seems to begin in the trias; only one of them survives; the two most abundant races are exclusively fossil. We seem here to behold a group capable of striking variation at one and that the earliest epoch, and of long continuing perseverance in the differences then occasioned.

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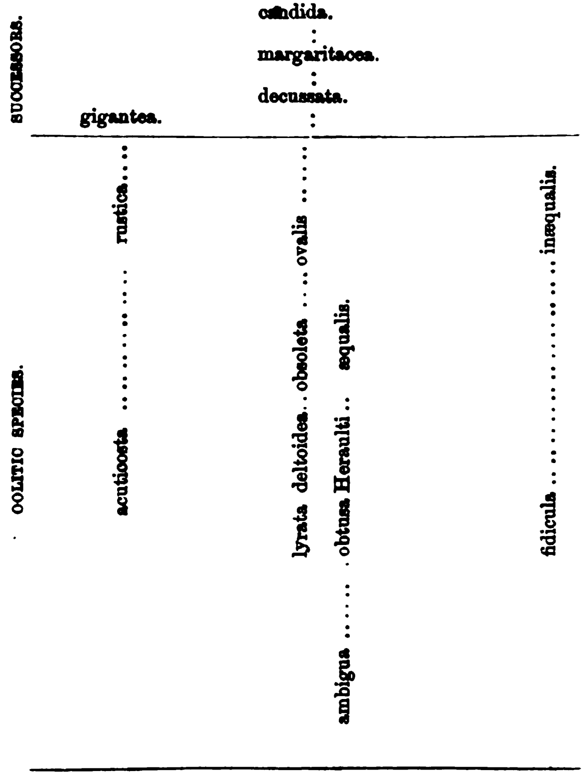
* The species thus marked are not British. That named T. Goldfussii by Alberti is a shell of the Keuper and muschelkalk; the same name is given by Agassiz to a very different oolitic form.

AFFINITIES OF OOLITIC PHOLADOMYÆ.



This group, so abundant in the oolites, begins probably in the lower lias with Pholadomya ambigua, Sowerby, and passes with easy modifications to the cretaceous system, and thence through analogous tertiary forms to the living species P. candida, a rare West Indian shell. This 'main-line' is flanked by a parallel through P. acuticosta to P. rustica and gigantea, and by another through P. fidicula to P. inæqualis, both families apparently becoming extinct with that oolitic kingdom which gave them their earliest homes.

Examples not less instructive, and all tending to the same conclusion, may be taken almost *ad libitum* from all the races of marine animals. In hundreds of instances we can trace backward in time the characteristic elements of generic structure to the earliest known type: in a small number of cases these lines of representative life, these probable genealogies, extend through all or nearly all the vast period which is known to us with certainty under the titles of palæozoic, mesozoic, and cainozoic life; a period which can only be expressed by the inconceivable symbols of a million, ten, nay a hundred millions of years. Yet during all that immensity of time, through all the physical changes which have happened to inorganic nature, lingula and rhynchonella have existed with little real difference, as if to shew the narrow limits within which modification by descent is restricted.

Take other cases—and very many can be taken—when the group to be examined is not living and has not been found among the earliest types, in these also the successive forms appear to have been subject to the same law of limited, though perhaps more considerable, changes; and the earliest types deviate in no essential points from the general plan of the family.

In all cases, then, we find for each race what appears an impassable point of its history—its first appearance among the relics of life, with all its essential characters. The world of life consists, or seems to consist, of a great number of families occupying a large range of time, and in this range admitting of many variations, mostly of slight (as terebratula), but sometimes of considerable extent (as trigonia); distinct from one another in all the course of their history; separate in their origin; often beginning their course at different epochs of time. How they came into existence we know not, nor can with much hope of success conjecture. For nothing known of the present inhabitants of the sea or land furnishes analogies of much cogency in this dark quest, though in regard to modification of form in descent there is plenty of experimental evidence in the living creation to help the palæontologist; as, on the other hand, the long history which he offers of what nature has done, what has been obtained by differentiation through a hundred millions of years, must ever tend to keep within right limits the attractive speculations of the biologist.

In a treatise like the present, which aims to gather from a limited district sure data to be combined with others in general reasoning, such speculations cannot be discussed with advantage, and are not worth discussion at all unless they have the quality of pointing to trains of useful further research, or serve to exhibit to inexperienced labourers the hopelessness of attempting the solution of problems for which there are no data.

The speculation of Darwin and many who preceded him, of indefinite change in animal and vegetable forms through length of time and variation of physical conditions, is of the highest theoretical and, at the same time, practical interest to the palæontologist. Given a primary, or what, for the purpose of this reasoning, may be called a primary form, can we trace it varying in any case, with time and circumstance, in such directions and to such an extent, that, if time and change of physical accompaniments were taken at a maximum, one generic type could be changed to another? Out of one original lamellibranchiate mollusk, placed at the limits of the monomyarian and dimyarian divisions, could avicula, perna, and crenatula &c. go forth as colonies in one direction; ctenodonta, cucullæa, arca in another; cypricardia, orthonota, and the mytilaceæ in a third[d]? This may not be beyond the range of research, but the scope of this treatise admits of only one suggestion regarding it.

If the amount of change which can certainly be recognized in natural groups extend only to specific distinctions in the course of all assignable time, and yet genera have given birth to others unlike themselves, how vast must have been the pre-Cambrian periods, to have allowed of this change from some one supposed primary into the many definite genera which the Cambrian rocks contain! Many times one hundred millions of years would be required if the slow process now observable in nature be taken as the measure of effect: we have no trace of such periods, and perhaps Astronomy and the Mathematical Theory of Heat will not allow of such vast duration to the habitable condition of the earth[e].

Was, then, the measure of change greater in early times? were these epochs 'rich in generic ideas,' as E. Forbes, an admirable leader in biology, now lost to science, conjectured? To his mind the more than usual introduction of new genera after the palæozoic ages presented that supposition, and he regarded the later periods as to a certain extent strongly marked off, and called them Neozoic. Previously, this seeming boundary, and another where the tertiaries begin, had been generally recognized as important to separate the palæozoic, mesozoic, and cainozoic strata and systems of life.

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[d] See remarks bearing on this subject in Memoirs of the Geological Survey, vol. ii. p. 264, 1848.

[e] Sir W. Thomson on Secular Cooling of the Earth, in Treatise on Nat. Phil., by Thomson and Tait, 1867.

If so, if in the earlier periods of the world's life-history there were epochs of uncommon genetic energy, this can only mean, in the language of science, epochs when physical conditions influential on life-form or life-production were combined to be exceptionally effective. What are these conditions? what were those combinations? Did they operate on the germ of life, or direct its first development, or modify both function and structure at every instant of its growth? These are questions to which, perhaps, we shall never be able to find satisfactory answers; yet even such hard problems must not be given up as desperate till we have learned how much or how little may be done, and worked our way toward a clearer view of the irremovable obstacle which must be encountered at last.

Life—that transitory force seated among elements of matter which itself selects and arranges; stationary in currents of molecular energy which it excites, directs, and renews; which is not matter, nor the sum of the forces of the elements of matter, taken in any proportions we please, and yet is known to us only in material forms, during limited periods of time; forms which are every moment undergoing variation, though composed of atoms which are themselves exempt from change and independent of time—surely here is an agency beyond the scrutiny of the agent; the

'. . . alte terminus hærens'

of the philosophy of unalterable 'centres of force.'

An interesting, and at the same time rather difficult, question has presented itself of late years in relation to those peculiar beds of the Bath oolite system known at the distant points of Stonesfield, Collyweston, and Brandsby. Were the slaty strata of these three localities deposited contemporaneously, or may their remarkable analogies both in structure and organic contents be understood as due to similarity of local conditions, which occurred at different points of time in different parts of the sea-bed?

One of my visits to Easton and Collyweston was made with Sir R. I. Murchison in 1831. We then obtained complete sections of the workings for slate, and took notes of the most frequent organic remains. Among other results was a conviction in my mind that both in plants and animal remains, in mineral character and structural aspect, and place in the strata, this slaty and flaggy series corresponded very closely with the flag and slate of Brandsby in Yorkshire.

Lately, on reviewing the notes then taken, and revisiting the quarries, I have found this opinion confirmed, and at the same time cannot but remark, along with a certain difference in fossils and mineral aspect from the Stonesfield beds, the analogy of the whole series in respect of the physical circumstances of their deposition.

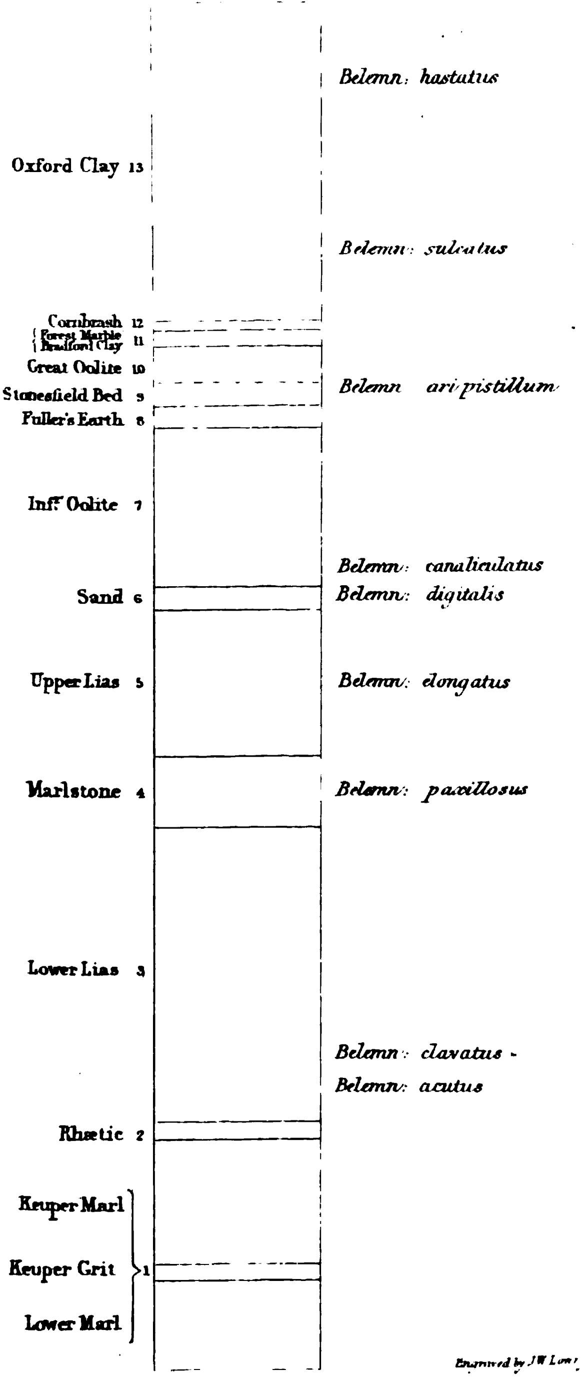
The sections at and near Collyweston may be thus represented in general terms:—

Cornbrash much as in Oxfordshire.
Forest marble and clays much as near Stonesfield.
Great oolite (called 'Rubble' and 'Cale') of white, yellowish, or pinkish tints, like that of Ketton. 8 to 12 feet.
NORTHAMPTON SANDS.
Sandy series (called 'Bedding-sand') with remarkable concretionary curves, or 'Potlids,' like those of Stonesfield. 3 feet where thickest.
Brown hard oolite in thin beds, graduating upwards to the sand (called 'Brood'). 4 or 5 feet.
'Limestone'—burnt for lime; hard, compact stone.
Solid irregular sandstone, called 'Bitch.'
The slate beds, 2 to 3 or 4 feet; blue in the cores.
Sands of yellow or brown colour (supposed to be 9 feet thick).
Clay thin, but yielding water.
Brown ferruginous rock, supposed to be 50 feet thick; locally 'Ironstone.'
Upper lias clay. 150 feet.

Comparing this section taken in Northamptonshire with those in Oxfordshire mentioned in an earlier part of the volume, great analogy will appear. The Stonesfield and the Collyweston beds lie between the Great oolite and the lias; they constitute part of a group of sandy strata, which in the lower or lowest parts become in places highly ferruginous; and parts are sufficiently proved in Northamptonshire to belong to the Inferior oolite, probably the lower part of it. According to this view, the two tracts of slaty rock belong to some part of the series between the Great oolite (upper part) and the Inferior oolite (lower part).

When we compare the fossils of the two tracts, the first im-

Section of Mesozoic Strata in Gloucestershire.



Engraved by J.W. Lowry.

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pression must be of similitude between them. In each case there is abundance of conchifera, fewer gasteropoda, still fewer cephalopoda. Plants of terrestrial growth occur in both, and are much alike.

In the Collyweston slates, among the more common bivalve shells we have of monomyaria—

Avicula, a small species in abundance.
Gervillia acuta in great profusion.
Pinna cuneata frequent.

And of dimyaria—

Astarte elegans.
Cardium cognatum.
Ceromya Bajociana.
Modiola imbricata.
Modiola Sowerbyana.
Myacites æqualis.
Trigonia impressa.
Unicardium gibbosum.

These are all frequent, and sometimes very plentiful, with valves in the original apposition, or opened, but not disjoined; in this respect the resemblance to the Brandsby slate is perfect.

This list affords no sure ground for joining or separating the zones of Collyweston and Stonesfield; but may be trusted so far as to confirm the influence obtained from the comparative sections. These slaty rocks may very naturally be regarded as belonging to one calcareo-arenaceous group of strata, which, by reason of the absence of fuller's-earth clays, does really include the lower part of the Great oolite, with some portion not yet clearly detertermined of the Inferior oolite. And so we leave it for further research[f].

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[f] For much information on the Northampton sands, consult Sharp in Geol. Proc. vol. xxvi. 1870.

CHAPTER XV.

PURBECK BEDS AND IRON-SAND OF SHOTOVER.

Not without change of level in the solid land, but without angular disturbance of the sea-bed, as far as is yet known, the marine series of Portland was succeeded in the same area by beds of estuarine, lacustrine, and fluviatile origin. In the Isle of Purbeck the earliest consist of fresh-water and estuarine shelly limestones and marls, a little varied by shallow marine deposits; and these are followed by sands and sandstones interstratified with marls and clays and fresh-water limestones, to the extent of a thousand feet in depth, called 'Wealden.' In the Vale of Wardour a more limited series appears, which consists mostly of fresh-water marls and thin limestones; at Swindon the marine top of the Portland is covered by a slight addition of fresh-water 'Purbeck' beds; while at Shotover, and near Aylesbury and Brill, such beds are themselves capped by a variety of sandstones, sands, and clays, which contain fresh-water shells, and constitute truly a 'Wealden' formation.

From the earliest days of geological inquiry in England, the range of sand-hills on the north side of the cretaceous basin of London, rich in ochre, fuller's-earth, and sands of many colours, has been the subject of frequent examination. As early as 1723, Holloway[a], writing to Woodward, traces the range, and describes its geographical relations and principal products; Smith, in 1800–5, mapped its course, identified it, as he thought, with the iron-sand of Wilts, Kent, and Sussex, and placed it in his map (1815) between the gault and the Portland rocks. Conybeare[b] took a lively interest in the same rocks, and, from personal research, described them in Shotover Hill, and through a considerable tract to the north-east, referring them, as Smith had done, to the iron-sand, a group in which he, like Smith, included the Hastings sands. At this time, however (1822), the term 'iron-sand' included portions both of lower greensand and Hastings sands, the complete distinction between these two groups not being as yet reached.

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[a] Phil. Trans. xxxii. p. 419.

[b] Geol. Engl. and Wales, pp. 136-143.

Dr. Fitton, whose memoirs on the greensands and other strata below the chalk have preserved the honour of England in regard to the geology of some parts of the secondary rocks, appears, as early as 1827[c], to have traced Purbeck deposits at one point beyond the northern outcrop of the chalk-hills of Buckinghamshire, viz. at Whitchurch, near Aylesbury, where white fissile calcareous beds overlie the Portland rocks, and contain Cyclades and Cypridæ.

In the year 1831 I was the companion of my great predecessor, Buckland, and his friend Conybeare, in an examination of the strata in Shotover Hill and Brill Hill. We traced in succession the members of the coralline oolite and Portland oolite groups, and searched in vain for organic remains amidst the ochraceous sands of the uppermost deposits of these hills.

In 1833 (Dec. 4), Hugh E. Strickland, then beginning to unfold those qualities which so much endeared him to his many friends, sent to Mr. Greenough a notice of the occurrence, on Shotover Hill, of imperfect casts of fossils which he believed to belong to the fresh-water genus Paludina. They were discovered by one of my earliest friends, the Rev. H. Jelly, of Bath, in a sand-pit on the brow of the hill, much above the level of the Portland rocks[d].

Dr. Fitton's great 'Memoir on the Strata below the Chalk[e]' refers to the same fact, adding, that the shells appear to belong to five species, three like Paludina, one small bivalve like Cyclas, and one larger bivalve like Unio; but, according to Dr. Fitton, the specimens found were all too imperfect to admit of precise determination, and were none of them so unlike some of the species which occur in the lower greensand as absolutely to exclude them from that formation[f].

In 1847 I accompanied Mr. Strickland in a walk up Shotover

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[c] Geol. Proc., June 1827, i. p. 26.

[d] Geol. Proc. ii. p. 6. The specimens are preserved in the Geological Society's Museum.

[e] Geol. Trans., Second Series, iv. 1836.

[f] Memoir, p. 275.

Hill; but we found no shells in the iron-sands, nor did it then appear that my friend had much expectation of adding to the facts he had already communicated. He must, however, during the period between 1847 and 1854 have been more successful; for I find in the Oxford Museum a remarkable specimen of Unio, which he discovered not far from the summit of the hill; and it is known that, in explaining to his class the geology of the vicinity of Oxford, he insisted on the probable fresh-water origin of the Shotover sands, and even traced out in imagination the course of the river-action to which they were due.

In 1854 I first conducted my class to Shotover, and engaged thirty or forty busy hands to renew the search in the iron-sands. We were more successful than our predecessors, and have on this and subsequent occasions gathered a few Conchifera and Gasteropoda, and plenty of coniferous wood. What seem to be cavities left by Cypridæ also occur, among other hollows due to a different cause, in the ferruginous portion of the thick mass of sands and their clays which overlie the Portland rocks; but I cannot say their recognition is certain.

In ascending Shotover from Oxford we meet (see sections, Plate XVI, figs. 1 and 2)—

A. The Oxford clay, with its usual characters. This deposit has been penetrated, by a boring for water at St. Clement's, to a depth of 400 feet. (Add 70 for the higher beds up to the calcareous grit.) The lower parts, which are seen but rarely in the Oxford district, yield Ammonites Duncani; the upper parts, Ammonites vertebralis. Gryphæa dilatata appears in the upper half; and bones of Plesiosaurus occur both in the upper and the lower parts.

B. Calc-grit, or sands with cherty and shelly bands, containing the usual fossils—Pinna, Ammonites vertebralis, &c.

C. Coralline oolite, with shelly rag-beds. In this tract the oolite is superior, the shelly rag inferior.

Isastræa.
Cidaris.
Nucleolites.
Clypeus.
Lima.
Ostrea gregarea.
Pecten lævis, &c.
Belemnites abbreviatus.
Ammonites catena.
„ perarmatus.
Chemnitzia.
Turbo, &c.

The top of the rock is waterworn.

D. Kimmeridge clay. Here only about 100 feet thick. At its base are scattered a few Coprolites; a few feet upward we find Thracia depressa, Gryphæa virgula; still higher, two 'flats' of Ostrea deltoidea; and at a height of fifteen feet a limestone-band, partly septariate, yielding Rhynchonella inconstans, and occasionally Pleiosaurian, Ichthyosaurian, and Steneosaurian bones, which also occur below it.

E. The Portland sands, with included rock-bands and hard nodules, rich in shells, 70 or 80 feet. The most cemented masses of rock in the lower part have been quarried. The uppermost part is greensand; and small grains of silicate of iron are scattered through the whole of the rock. There is an included bed of clay, three feet thick. Fossils of the Portland series are traced through the whole, even up to the top, such as—

Astarte cuneata.
Cardium dissimile.
Ostrea expansa.
Pecten lamellosus.
Perna mytilloides.
Pholadomya rustica.
Trigonia gibbosa.
Buccinum naticoideum.
Cerithium portlandicum.
Littorina paucisulcata.
Natica elegans.
Pleurotomaria rugata.
Ammonites triplex.
(No Belemnite is seen.)

F. Iron-sand-and-ochre-series to the top of the hill, 80 feet. The whole consists of yellow and white sands, varied with brown and even black colour,—sandstones, sometimes cherty;—nodular and geodic formations of oxide of iron,—bands of white clay,—and local accumulations of ochre. Mr. Conybeare presents the following section[g]:—

	ft.	in.
Beds of highly ferruginous grit, forming the summit of the hill	6	0
Grey sand	3	0
Ferruginous concretions	1	0
Yellow sand	6	0
Cream-coloured loam	4	0
Ochre	0	6
Clay	thickness not given.	
Ochre		
Ferruginous sands, cherty and argillaceous loams of a deep cream-colour	40	0

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[g] Geol. of England, p. 139.

Thus above 60 feet are assigned to the group of iron-sands. It is in the lower group, which also contains ochre, that the shells occur which were first noticed by Mr. Jelly. He found them about 30 feet above the Portland rocks; but my observations lead to the conclusion that they occur in all parts of the deposit, from the very base to nearly the top of the hill. They have, however, never been seen by me in the very uppermost sandstones, about 20 feet thick.

In the uppermost layer, at the east end of the great pit on the north-eastern slope, which is really pisolitic or oolitic iron ore, half decomposed into ochre, I observe a few traces of what seem to be organic forms, but as yet nothing definite has been recognized. That pit, when in full work some years ago, presented the following section of beds, which probably are the highest of the series :—

	ft.	in.
Ferruginous sandstone formed in irregular beds, with irony joints and concretions, part of it a true iron ore	12	0
Blue, pale, laminated, sandy clay	3	0
Yellow sand, laminated, the upper surface irregular	3	0
Pale yellow and white stripy sand	2 0 to 3	0
Blue clay, with brown band of clay at the bottom	1	0
Yellow, pale brown sands	4	0
Pale blue sandy clay	1	2
Pale laminated sand	0	2
Pale sandy clay	0	10
Yellow, white, and reddened sands	4	0
Blue clay	0	3
Yellow ochre of good quality	0	3

The layers of these cherts, sandstones, geodes, clays, loam, and ochre are very irregular in extent and thickness, yet not in such a way as to suggest more than gentle current-action. There is very little false-bedding; the layers are mostly undulated, and the concretionary tendency of the oxide of iron has produced ramifying and geodic masses much harder than the rest. The shells are now almost confined to these hard irony masses, perhaps because there only preserved from destructive solutions. The white sands and white clays are in continuous deposits, the latter in very thin laminæ.

The organic remains hitherto found in the upper sands of Shotover, and especially in the irony parts of the deposit, consist of—

Coniferous wood in fragments. A small coniferous stem. Leaf of Pecopteris.

CRUSTACEA.

Cypris? It seems to be recognized in some of the minute hollows which abound in the iron-bands, but these being of oolitic texture, makes the recognition doubtful.

CONCHIFERA.

Unio Stricklandii, new species. Outline transversely ovate, without posterior sinuosity; beaks depressed; ligament very prominent; posterior area marked by numerous and regular rugæ. (Pl. XVI. fig. 3.) It differs from U. valdensis in figure and in the characters about the ligament and posterior slopes. The beaks are much eroded. Breadth above two inches; length a little above half the breadth. Found by Mr. Strickland twenty or thirty feet below the top of Shotover Hill.

Unio porrectus. *Sow.* Near Cuddesden.

Unio subtruncatus (?). *Sow.* Fitton's Memoir, pl. xxi. fig. 15. Shell very thin, with delicate transverse striæ. (Pl. XVI. fig. 4.) The shell figured in Fitton's Memoir agrees exactly in shape, but does not shew the external surface. Shotover Hill.

Cyrena media. *Sow.* M. C. pl. 527, fig. 2; so it appears to me. (Pl. XVI. fig. 5.)

Other forms of Conchifera occur, but are not clearly made out. Shotover Hill.

GASTEROPODA.

Paludina elongata. *Sow.* M. C. pl. 509, figs. 1, 2. *Rare.* Shotover Hill, near Cuddesden.

Paludina Sussexiensis. *Mant.* Fitton's Memoir, pl. xxii. fig. 6. *Rare.* (Pl. XVI. fig. 6.) Some specimens are shorter than the figure, and have the air of Littorina.

Paludina subangulata. n. sp. (Pl. XVI. fig. 7.) Ovato-conical, the volutions slightly angular or subcarinate, and striated spirally above the carina, not below it. *Frequent.* The obscure carina sometimes appears on shells quite deficient of spiral striæ; they are perhaps worn specimens. Shotover Hill.

Paludina ornata. *Phil.* Ovato-conical; the volutions very rounded, and covered with spiral striæ, which sometimes appear larger and smaller alternately, and are crossed by distinct lines of growth. (Pl. XVI. fig. 8.) *Frequent.* This shell looks as much like Cyclostoma as any of the spirally-threaded Paludinæ known to me. The spiral threads are, in some specimens, more prominent about the middle of the volution. Shotover Hill.

There is a colour-band on one of my spiral shells; but I cannot determine the species.

On this list (which omits only some forms too imperfect for notice) it may be remarked,—1. That very few more organic forms are to be expected from the western side of Shotover, the part as yet chiefly examined; for the specimens include perhaps only two or three not found by Jelly and mentioned by Strickland and Fitton. 2. That none of the marine forms usual in lower greensand occur in it. 3. That while the general analogy is to estuarine and fresh-water species, and while some of the species seem to be either the same or very nearly the same as known Mid-Wealden types, there are characters in some of the spiral shells worthy of remark, as tending perhaps towards Littorina or Cyclostoma as much as to Paludina.

Admitting, on the evidence which has been adduced, that the iron-sands of Shotover, nearly to the top, were accumulated under the influence of river-currents, which scattered the remains of fresh-water organic life among them, we find this conclusion strengthened by the facts, that at Combe Wood and Garsington, a little further to the south of Shotover, these sands were seen by Dr. Fitton to cover a Purbeck deposit—'Malm,' with Paludina elongata and another species, Planorbis (?), two species of Mytilus, Modiola, and Cypris. Below is the Portland rock.

'The section at Combe Wood consists of—
1. Reddish loamy soil, passing into
2. Ferruginous sand (*lower green*).
3. A thin bed of very tough clay (fuller's-earth ?); which with 2. enters into and follows the deep erosions and irregularities at the top of 4.
4. *Purbeck.* Stone and soft rubbly matter (the 'malm' of the pits at Garsington), containing fresh-water shells like those of that place: Cypris; Mytilus, two species; Modiola; *Paludina elongata*, and perhaps another species ? Planorbis ? Some portions of the stone are compact and uniform, with the usual characters of fresh-water limestone; others, though containing the same fossils, are composed of grey and brownish fine-grained oolite, in which a very small univalve, perhaps a *Paludina*, occurs in such numbers as in some places to form nearly the whole mass.'

(Portland stone below.)

At Garsington the following section was observed by Dr. Fitton:—

	ft.	in.
1. Loamy soil	2	0
2. *a.* Ferruginous brown sand, including portions like umber, and irregular seams of clay (fuller's-earth ?). It contains two patches of greenish sand	8	0
b. A band of yellow ochre, about half an inch thick . . .		
c. A thin bed of uniform tough clay (fuller's-earth) in wax-like pieces, polished by motion under pressure		
3. *Malm*, an agglomerate, composed of stone and softer marl-like matter much decomposed.	4	0
Among the components are—		
a. Light greenish-grey marl, like some beds of the lowest chalk; containing at the upper part detached fragments of silicified coniferous wood, like that of Portland, and portions of bone.		
b. Firmer pieces of stone, with some oolitic particles, including small spiral univalves—*Paludina*, perhaps of two species ? a Planorbis ? Mytilus and Cypris.		
c. At the lower part the mass consists of larger pieces of uniform limestone, in some places like the 'Pendle' of the pits at Whitchurch, and including small Paludinæ with other small spiral univalves, Mytili and Cypris. Some of these pieces have a botryoidal, others a finely oolitic, others a compact texture.		

(Portland stone below.)

At Great Hazeley the Portland stone has been quarried from ancient time, and it there furnishes a limited supply of better quality than usual for building, being of good colour and firm and equal texture, except for the shells, which, however, mostly lie in bands. A thick grey or greenish sand is at the bottom; over this the stony series, the lower part workable freestone, the top hard splintery limestone, 2 feet thick, much jointed, fit for roads and rough walling, called 'Curl,' which suggests the idea of Purbeck beds. This is immediately followed by the iron-sand and clay series.

SECTION AT GREAT HAZELEY.

		ft.	in.
12.	Soil, uniformly spread, with drift on the surface of chalk flints, and red grit pebbles.		
11.	Brown sand and laminated ferruginous sandstone, or ironstone, with some argillaceous parts. In this bed Paludina elongata and others, lying in separate short tracts or nests, as at Shotover Hill. Thickness, 3 to 5 feet seen.		
10.	The lower surface is undulated in a surprising manner, and rests on a yellowish or white laminated clay, with thin brown irony bands. Thickness 3 to 5 feet. The bottom rests level on the next bed.		
9.	Brown ferruginous level sands, false bedded, the laminæ dipping N.W.	1	6
8.	Dark irony band	0	3
7.	White laminated clay	1	6
6.	Dark irony band, false bedded as above	1	0
5.	Brown ferruginous band, false bedded as above	2	6
4.	White argillaceous laminated bands	2	0
3.	Blue clay bands, laminated	0	9
2.	White laminated clay bands	0	6
1.	Brown laminated clay bands	0	6

Curl stone of the Purbeck or Portland series below.

The sections at Brill have been re-examined at different times, and the extension of the characters of the iron-sand of Shotover to that interesting hill made more evident by the discovery of fresh-water shells there in the higher beds. In the twin hills of Muswell and Brill the observer has the advantage of seeing a large number of quarries and other openings for stone, sand, and clay, and the natural accompaniments of such strata, many perennial springs of sweet water, very little charged with iron or lime, by their free percolation to the depth of a few yards. The well-known and strongly-impregnated chalybeate of Brill rises not out of these strata at all, but in low ground occupied by Kimmeridge clay on the eastern side of the hill.

This clay appears in the deeply-cut hollow between Muswell Hill and Brill, and is worked for bricks. Portland stone lies over it; then follows what represents the Purbeck beds; and iron-sand with its clays caps the whole. The whole line of road over Muswell Hill is explored by many pits which disclose the iron-sand series in a satisfactory manner. If we combine the sections on the whole line from Brill over Muswell Hill, the result will stand thus:—

		ft.	in.
Iron-sand series, 50 or 60 feet, consisting of—	Brown ferruginous rock, partly arenaceous, partly oolitic, with some bands of Cyrenæ.		
	Yellow and white sands, with clay bands, and iron bands.		
	Brown ferruginous lumpy sandstone, with clay bands in places.		
Purbeck series, 10 feet.	White calcareous laminated band, marly or stony	1	0
	Grey argillaceous beds	3	0
	White calcareous, marly or stony	2	0
	Grey clay	0	6
	White laminated stone	1	0
	Grey clay	1	0
	White stone	1	0
	Grey clay	0	6

One of these stone-beds is drilled on the upper surface by some tubicolous animal; the stone is occasionally close-grained, like the 'curl' of Hazeley.

Portland rock below, in lumpy shelly masses of small thickness.

On the line by Long Crendon to Thame are many excavations, some of which shew traces of Purbeck beds and of the incumbent ferruginous sands. The representative of the Purbeck beds is chiefly clay, as in Shotover Hill; but at Long Crendon the 'malm' rubble of Garsington and Combe Wood is also seen above the Portland rock. In the neighbourhood of Aylesbury the Purbeck beds again become distinct, and are covered by white or ferruginous sands of considerable thickness about Hartwell, whence some was taken for glass-making. At Dinton variously-coloured clays rest on laminated stone and clays, the former compact or decomposed to 'malm,' 'with spiral univalves, small modiolæ, and cyclas' (Fitton). At Bishopstone, in the same neighbourhood, alternating clays and limestones (one band of clay very dark) rest upon white marly limestones, with cyprides, which yielded remains of fishes and turtles.

Dr. Fitton was fortunate in finding in the pit at Bishopstone the following interesting succession:—

	ft. in.	ft. in.
1. Soil.		
2. Fuller's-earth, greenish and brown Iridescent Mytili in this bed.	0 1 to	1 0
3. Rubble, white fresh-water limestone, decomposed, containing Cypris and casts of small Paludinæ in calcareous spur		4 0
4. Clay and stone:		
a. Light olive-greenish fuller's-earth	0 4	
b. Soft limestone	0 6	
c. Fuller's-earth like *a.*	0 2	
d. Stone like *b.*	0 3	
e. Fuller's-earth	0 2	
		1 5
5. 'Sandstone'—a firm calciferous grit, with traces of deposition surfaces and ripple-mark	0 6 to	0 9
6. Sand alternating with ochre and clay:		
a. Sandy ochreous clay	0 2	
b. Dark greenish fuller's-earth	0 2	
c. Greenish-grey sand, including scales of fishes	0 7	
		0 11
7. Fissile calciferous clay or marl, passing into stone. In the upper part iridescent Mytili. *a.* Dark bluish clay with Cypris, Unio, and scales of Lepidotus. *b.* Clay, hard, with Cypris. *c.* Clay, still harder, approaching to stone, with Cypris. All these divisions contain Cypris Valdensis, and another species; a small smooth Modiola, a striated species; and Cyclas parva.		1 6
8. 'Pendle,' fissile argillaceous limestone, with Cypris, Cyclas, Modiola, Paludina, etc., as in the 'malm' at Garsington. Sometimes a depressed Planorbis as at Garsington		0 6
(Portland rock below.)		

Close to Hartwell I observed an excavation shewing—

	ft.	in.
'Rubble,' white marly limestone of varied structure, with few fossils	4	6
Three thin greenish marly layers, with two courses of pale stone	1	3
Brown, blue, and ferruginous layers (*Natica*)	1	6
Marly layers	0	8
'Pendle' stone	0	10
Marly layers, with insects, fishes, and parts of a turtle	0	10
Hard blue stone	1	2
Dark laminated band.		

Under these layers, which appear partly of marine and partly of fresh-water origin, like some in the Isle of Purbeck, are three thicker beds, in all 7 ft. 8 in., and then 6 ft. of loam, and 1 ft. 8 in. of hard blue stone with spiral shells, and water. If these be taken for Portland rock, all the layers above may safely be regarded as representing the Purbeck series. Above them lie various coloured sands, red, white, and brown, and these are occasionally cemented into pebbly rock. These may be seen in the hill above Stone.

One section reads thus:—

Pebbly rock.
Yellow sand.
Irony and pebbly sand, with wood.
White clays.
White and yellow clays and fuller's-earth.
White sand.
Striped yellow and pebbly sand.

20 to 30 feet.

This is obviously of the same series as the iron-sands of Shotover, which are of greater thickness and yield more abundant evidence of fluviatile affluents.

Similar facts occur at Whitchurch in Buckinghamshire.

Thus the iron-sand of Shotover is connected with the more extensive deposits of Buckinghamshire and Bedfordshire; and the ancient generalization of Holloway, who united in one deposit the sands, ochres, and fuller's-earth of Woburn and Shotover, is confirmed.

Smith, who regarded these sands as of the same great group as the Hastings sands—in this agreeing with Conybeare—records the occurrence, at Steppingley Park, near Woburn, of gault over the sands, and containing its characteristic ammonites. Thus we find the 'iron-sands' to be inferior to gault, and superior to Purbeck beds; they may at present, with much probability, be referred to the Hastings sands; it is, however, possible that they may be an estuarine deposit of the lower greensand age.

It is to be hoped that the Geological Survey, in its progress to the north-east, will furnish new data, and especially additional evidence from organic remains, for the determination of the physical condition of this region in the later oolitic period. I regard it, however, as certain, that much of the so-called 'iron-sand' on the northern outcrop of the London basin must be ranked among estuarine deposits.

At the present time it can hardly be said that true iron-sands occur in the range of country west of Oxford, nor is there much

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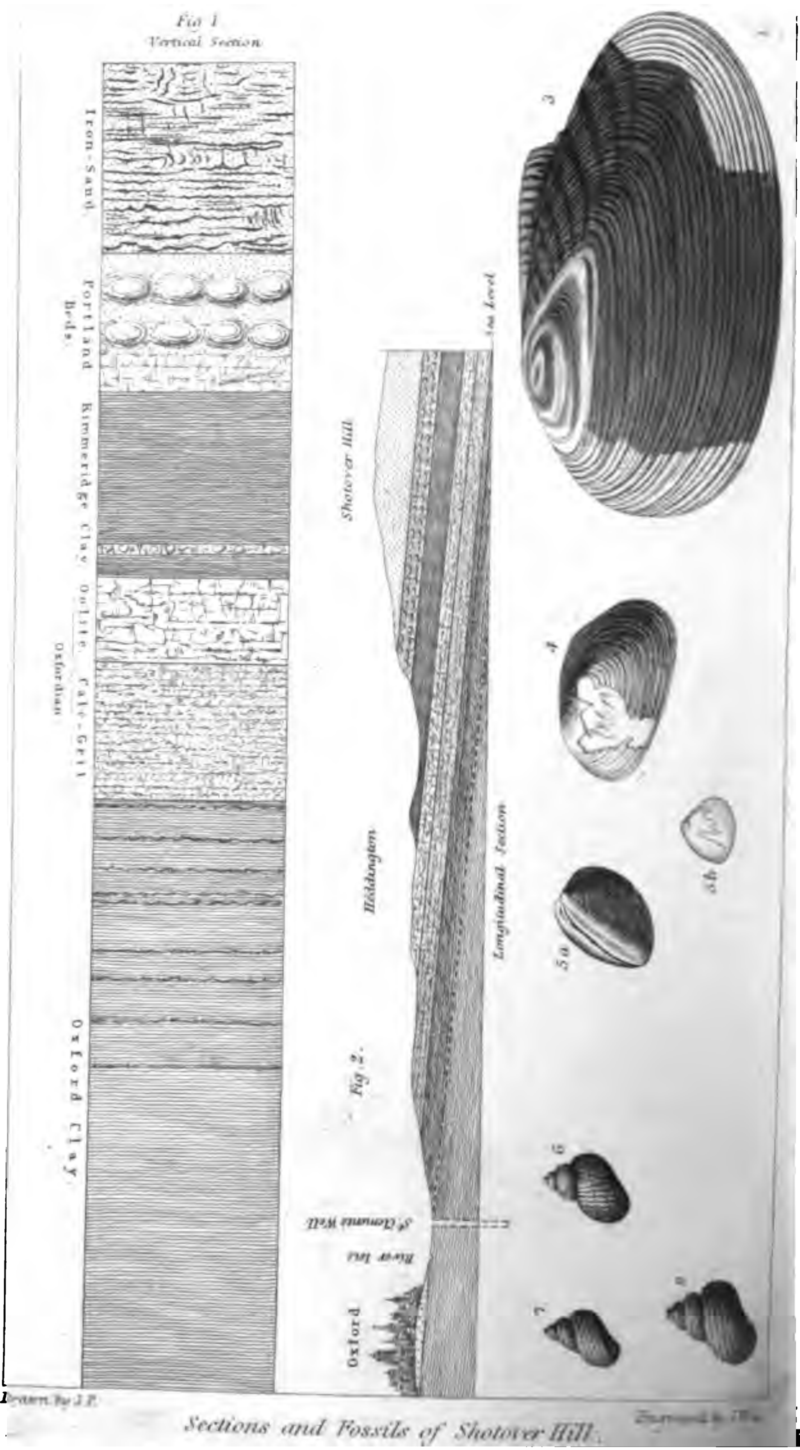

Drawn by J.P.

Engraved by [illegible]

Sections and Fossils of Shotover Hill.

chance of finding such except near Faringdon and Swindon. The low mound south of Faringdon Folly contains sands of similar appearance, and there is distinct trace of Purbeck beds at Swindon.

Dr. Fitton's account of the section at Swindon is in these words[a]:—

> '*Purbeck Strata.*—The only indication of this member of the Wealden which I found at Swindon, were detached masses of botryoidal limestone, like the middle of the "Cap" in Portland, and fragments of dark brown silicified wood,—fallen, I have no doubt, from the top of the quarries, though supposed by the workmen to occur in the midst of the stone itself. In the looser matter also, near the top of the quarries, and above beds of the Portland stone, are masses including very numerous casts of marine shells (apparently Lucina and Cytherea), in which the cementing substance has the aspect of fresh-water limestone, and is scarcely to be distinguished from a stone of the same yellowish hue, within the Purbeck series, near Ridge in the Vale of Wardour; but in the latter the casts are those of *fresh-water* species, especially Cyclades.'

Clay occurs in detached portions above the Portland stone in the great quarry at Swindon, but Dr. Fitton was not enabled to determine the formation to which it ought to be referred.

The result of two examinations of the quarries and other excavations at Swindon made by myself, was to confirm these observations of Dr. Fitton. No trace of incumbent sands like those of Hastings.

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[a] Trans. of Geol. Soc. of London, Second Series, vol. iv. 1836.

EXPLANATION OF PLATE XVI.

1. Vertical section of the strata in Shotover Hill.
2. Section from Oxford to Shotover Hill.
3. Unio Stricklandii. *Phillips.* (The lighter tint indicates the restored portions at the extremities.)
4. Unio subtruncatus. *Sowerby.*
5. Cyrena media. *Sowerby.* *a.* Oblique view, enlarged; *b.* Side view, nat. size.
6. Paludina Sussexiensis. *Sowerby.*
7. Paludina subangulata. *Phillips.*
8. Paludina ornata. *Phillips.*

CHAPTER XVI.

THE CRETACEOUS SYSTEM.

THOUGH not fully exhibited in the district round Oxford, there are traces of all the parts of this great system, and much diversity in some of the members of it, especially the glauconitic parts—upper and lower greensand.

Upper chalk, with bands and nodules of flint.
Middle chalk, including the 'chalk rock' of Whitaker.
Lower chalk, with marly partings, and no flints.

Upper greensand, or fine sandy chalk.
Gault, pale blue laminated clay.
Lower greensand, often ferruginous and pebbly.

LOWER GREENSAND AND CONGLOMERATE.

The passage from the oolitic to the cretaceous system of strata is nowhere in the British islands very gradual, either in respect of concordant deposition, mineral composition, or organic life. The estuarine and fresh-water conditions manifested at intervals in the oolitic series, and especially abundant in the upper part, may be supposed to have continued in the Wealden, while elsewhere the neocomian beds of marine origin had contemporaneously entered an appearance. Confining our attention to the ample range of country accessible from Oxford, between the districts of Devizes and Cambridge, we find almost everywhere the gault clay in fair antecedence to the upper greensand, which is not always clearly separable from lower chalk and upper chalk. But the beds below the gault are just as often Kimmeridge clay in the Vale of North Wilts, or Portland rock in the Vale of Aylesbury, as lower greensand, so prevalent is the unconformity between the truly cretaceous beds (including gault) and the somewhat perplexing groups between that stratum and the well-defined Kimmeridge clay. These groups are perplexing from their irregular and unequal distribution, both as to area and level, and from the almost continual change of mineral character. In the Portland rock, however, the organic remains are of a clear and nearly uniform and truly oolitic type; the Shotover sands interpose a truly estuarine or fresh-water series; and the other sandy and conglomerate masses, which we collect under the title of lower greensand, distinguish themselves from both by a large number of quite different fossils of a cretaceous aspect.

Originally unequal and irregular in distribution as a floor of the gault, the lower greensand deposits have since been cut up at the surface into detached pieces, usually forming rather conspicuous tops of hills; and these, when carefully compared, offer, even in a limited space of country, obvious differences; some tracts being richly fossiliferous, others devoid of them; some being chloritic sand, others ferruginous sand, others shelly or pebbly conglomerate.

It will be sufficient for our purpose to take those tracts where the characters of deposition and the facts of organic life are well pronounced; such as Seend in Wiltshire, Faringdon in Berkshire, and the country about Culham and Nuneham in Oxfordshire.

We are indebted to Mr. Cunnington of Devizes for an instructive notice of this deposit, with fossils, as it occurs at Seend near Devizes[a].

At Seend, in a road-cutting, the lower greensand was found resting on Kimmeridge clay, well characterized, and in particular having masses of septaria marked by boring shells of the lower greensand age, the shells and the sand remaining in the holes.

The series in this vicinity consisted of upper greensand, 90 feet, gault, 80; and then followed in downward order—

1. Sands above, followed by—2. Irony sandstone; 3. Yellowish sand; 4. Irony sandstone, with fossils; 5. Dark green and brown sands; 6. Masses of quartzose gravelly sand and stone, not very ferruginous, but very fossiliferous; 7. Kimmeridge clay.

The fossils in the sandy and gravelly beds are marine, and considerably varied; but the sponges, so common at Faringdon, are not noticed here. Terebratulæ are numerous. In the lower beds of the sand rolled fossils and bouldered masses derived from the Kimmeridge clay are abundant. The ironstone was smelted in ancient times.

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[a] Geol. Journal, vi. 453 (1850).

Passing now to Faringdon, we find that picturesque town seated amidst banks of Coralline oolite and Kimmeridge clay, capped here and there by sandy hills and broad floors of shelly gravels. In the detached and dome-shaped hill called the 'Folly,' on the east side of Faringdon, crowned by a conspicuous 'clump' of trees (510 feet above the sea), the sands are 100 feet thick, yellowish in colour at the surface, and divided by concretionary beds of sandstone and thin bands of ironstone. No fossils seen in the road sections, or in an open pit in a low hill by the road to Stanford.

Badbury Hill, west of Faringdon, and equal in height to the Clump, is also composed of sands and sandstone, more or less fossiliferous; among these being wood and a fern leaf in the sandstone which caps the whole[b].

This hill is not an insulated outlier like Faringdon Folly, but slopes obscurely down to the south, and expands in a broad dry surface of sands and conglomerate resting on Kimmeridge clay about the village of Coxwell.

This is the tract which yields the celebrated fossiliferous gravel, in large excavations begun in a flat tabular surface, to which the beds of conglomerate and loose gravels, shells, and sand are nearly conformed, much as in a district of 'crag,' to which these extensive old shell and sponge beaches bear no small resemblance.

In the largest of the pits about two acres of the rock gravel and sands have been excavated—part being in solid beds, one surface often marked by a scattering of small oysters. These beds when carefully examined are found to have a large nodular structure occupying the whole thickness, the intervening spaces being filled by the same materials not agglutinated. The layers are generally parallel, dipping slightly to the east, without false bedding. No clay bands, no layers of mere sand. The whole stands, when cut down, vertically like a wall. The pebbles are of quartz, metamorphic flinty slates of various hues, black, grey, and greenish.

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[b] Austen, Geol. Journal, vi. p. 457 (1850).

Amidst a multitude of sponges and shells which seem to have been aggregated on the old sea-shore, like some beaches, or more probably gathered in limited tracts of shallow sea, like 'sand-banks' in the German Ocean, many fossils are observed which appear to have been drifted from older strata. This appearance is not deceptive, for the mineral state and worn condition of these fossils confirm the suspicions at first raised by their forms. Mr. Sharpe[c] presents a list of twelve or more species, mostly from the Kimmeridge clay and coral rag, which adjoin the deposit; very few, if any, from the Portland rock, which in the course of its denudation was probably carried southward during and previous to the deposit of these beds. I have added a few species :—

Echinida	Cidaris intermedia	Of the Coral rag.
	„ florigemma	Of the Coral rag.
	Diadema depressum	Of the Coral rag.
Monomyaria	Exogyra nana	Of the Coral rag and Kimmeridge clay.
	„ virgula	Of the Kimmeridge clay.
	Ostrea deltoïdea	Of the Kimmeridge clay.
	Gryphæa dilatata	Of the Oxford clay.
	Pecten vimineus	Of the Coral rag.
	Perna mytiloïdes	Of the Kimmeridge clay and the Portland rock.
Dimyaria	Myacites recurvus	Of the Oxford clay or Kimmeridge clay.
	Belemnites Owenii, jun.	Of the Oxford clay.
	„ explanatus, jun.	Of the Kimmeridge clay.
	Ammonites—several fragments	Of the Oxford clay.
	Sphærodus gigas	Of the Kimmeridge clay.
	Ichthyosaurus	Teeth and vertebræ.
	Plesiosaurus	Vertebra.
	Teleosaurus	Teeth.

Further to the south, about Cole's Pits, Farnham, and Alfred's Hill, sands prevail, and gravel-beds appear in limited spaces, always resting on Kimmeridge clay, but fossils are rarely seen in any of the exposures.

Of other tracts containing small portions of lower greensand in the vicinity of Faringdon, it is only necessary to say that they conduct but a short way toward the chalk hills on the south, and that no continuous band of these rocks occurs at the base of those hills, or between them and Faringdon. On the contrary, the gault clay and upper greensand of that cretaceous range are found to rest on lower strata, viz. on Kimmeridge clay. Thus we have two cases of unconformity in this region between the Thames valley and the Wiltshire downs. (See Plate III.)

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[c] Geol. Journal, x. p. 182 (1853).

1. The lower greensand rests unconformably on the Kimmeridge clay, the lower part near Faringdon, no Portland being found between these strata.
2. The gault rests unconformably on the Kimmeridge clay (the upper part) south of Swindon, neither Portland nor lower greensand being observable between them.

These deficiencies of the Portland rock and lower greensand are clearly due to wasting of those deposits, such waste beginning after the Kimmeridge æra, and continuing at intervals till after the age of lower greensand. No wonder if, under such conditions, here and there Wealden beds of fluviatile origin as to the materials should be locally interpolated in the series of marine sediments.

We may now proceed to the country south of Oxford, where a considerable extent of surface is occupied by the lower greensand, though greatly disguised by an overspread of pleistocene drift.

Nuneham Park gives a succession of gault, lower greensand, and Kimmeridge clay; the sandy strata are somewhat ferruginous, coarse-grained, and pebbly. The stratum is really continuous to Culham on the south-west, Toot-Baldon, Marsh-Baldon, and Chiselhampton on the north-east and east. It appears in cliffs at Clifton-Hampden, above the Thames, and is found in the channel of that river. Here it is a strong ferruginous conglomerate, without fossils. At Toot-Baldon it caps a hill of Kimmeridge clay; and in its ferruginous beds some fossils have been found by myself, and also by the members of the Ordnance Survey. Ammonites Deshaysii is one of these.

One of the most interesting of the sections near Oxford is seen at Culham, on the northern bank of the Thames; and this may be compared with another in the line of railway near Culham Station, about a mile to the north-east, with a hill-capping at Toot-Baldon and a cliff-section at Clifden. I have been in the habit of taking my class to some of these localities for several years.

On entering the excavation at Culham we perceive about 40 feet of level-surfaced clays and sands, under a cover of flint-gravel mixed with worn shells of Gryphæa dilatata and other spolia of the adjacent country. Nearly the whole mass of the clays and sands excavated here is employed for brick-making; and the digging operations mix them much together. A slight glance at the section presents enough of uniformity to induce the belief that the whole might belong to one continuous deposit. If, under this impression, a palæontologist viewing the excavation should pick up Thracia depressa and Cardium striatulum, and obtain from the workmen teeth of pleiosaurus, he will probably write 'Kimmeridge clay' on the whole section. Another geologist, arriving when the clay is not being dug, may examine a different part of the deposit and find Ammonites dentatus and Belemnites minimus, and may colour on his map, 'undoubted gault.' But when, instructed by several visits, the whole section is clearly made out, we find two clays in the pit, of entirely different geological age, separated by a bed of sand apparently conformed to each—so far as this very limited area gives any evidence.

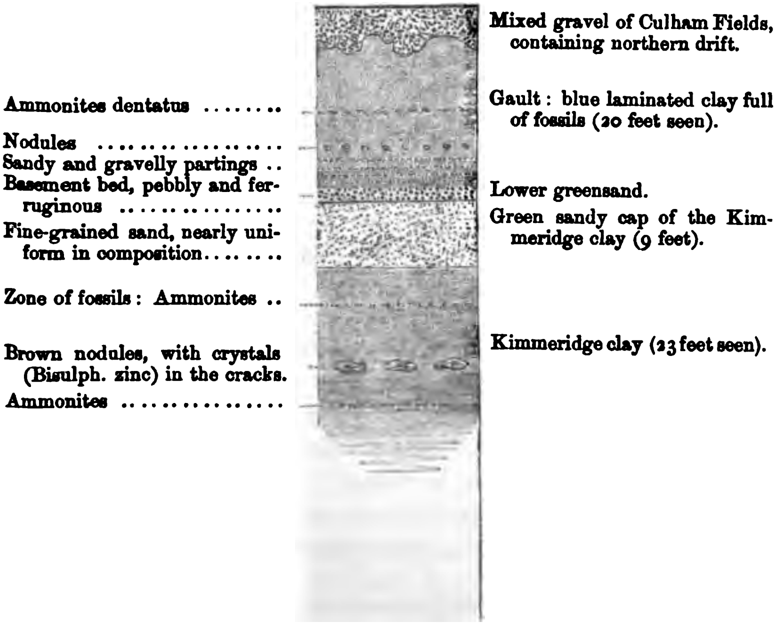
Mixed gravel of Culham Fields, containing northern drift.
Ammonites dentatus ....
Gault: blue laminated clay full of fossils (20 feet seen).
Nodules ....
Sandy and gravelly partings ..
Basement bed, pebbly and ferruginous ....
Lower greensand.
Fine-grained sand, nearly uniform in composition........
Green sandy cap of the Kimmeridge clay (9 feet).
Zone of fossils: Ammonites ..
Brown nodules, with crystals (Bisulph. zinc) in the cracks.
Kimmeridge clay (23 feet seen).
Ammonites ....

Diagram CXCVI. Section of the Strata at Culham, south of Oxford.

In descending from the gravelly surface deposit, we have about 10 feet of blue laminated clay, with the following fossils:—

Ammonites dentatus.
,, lautus.
Belemnites minimus.
Solarium conoideum.
Rostellaria.
Dentalium, probably D. decussatum.
Nucula pectinata.
Inoceramus concentricus (large).
Plicatula pectinoides.
Pecten quinquesulcatus.
Balanus.
Cyclocyathus Fittoni.
Coniferous wood.

Below these unequivocal gault layers the argillaceous deposits are striated with short drift laminæ of sand and small gravel. In these, by careful search, I found specimens of the ammonites mentioned above. These layers are about 5 feet thick, and gradually pass upward into the ordinary gault[d].

Below these sandy layers is a more specially pebbly band, in some places compacted together, in which I found what seems to be Pecten orbicularis. This band agrees in position with what may be termed the basement bed of the gault or the cap of the lower greensand at Folkestone.

A remarkable exhibition of a sand-rock with pebbles occurs in cliffs against the Thames at Clifden-Ferry. It is traversed by oxide of iron in nests, laminæ, and veins running in various directions. As far as the composition of the mass is concerned, this sand-rock resembles somewhat the Shotover irony rocks, and somewhat the pebbly lower greensand of Faringdon; but few fossils have been found in it.

Farther to the east, the iron-sand range becomes continuous by Woburn, Ampthill, Sandy, and Potton, and conspicuous over the broad plains chiefly formed on Oxford clay. The sandy series is streaked with iron laminæ in various forms, and generally stained of ochraceous tints derived from the iron oxides. Some white bands also occur. In this series it is rare to find any fossils; but towards the base of it appears a variable band of gravel, one foot or so in thickness, which is literally filled with fossils, many of them fragmentary, mostly water-worn. In a considerable proportion of the fossils bones are recognized, from different kinds of animals and different parts of the bodies. Among these vertebræ are frequent, and to them iguanodon, megalosaurus, plesiosaurus, and ichthyosaurus have contributed largely. There are very many teeth, some of iguanodon, some of megalosaurian, others of crocodilian affinity; besides these are defensive spines of hybodus and asteracanthus, teeth of sphærodus and pycnodus. Separate or surrounded by indurated clay are plenty of ammonites, rarely in a state to be identified for species, a few belemnites, a few gasteropods, a few oysters. Rarely a fragment of a cycadaceous stem rewards a search on the enormous heaps of the excavated gravel.

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[d] In this part of the series, probably, occurred a fine specimen of Ostrea macroptera, which came into the hands of my late friend Professor Walker, who resided at Culham.

The gravel is largely dug for its phosphatic wealth; bones, teeth, and nodules generally, contain more or less of this precious matter, and they are sorted according to their value, and, for a different reason, according to the size.

Thus a favourable opportunity occurs for collecting on a great scale a large variety of fossils; but they are generally found to have been much injured by rolling and mutual attrition in water.

In considering the history of this deposit, the geological age and circumstances of accumulation are the most important objects to be attained; and the most valuable evidence is furnished by the organic remains: for these, lying as they were placed by the agitated water, give more than suggestions of the processes which preceded their accumulation.

The geological date of the deposit may be safely taken as corresponding to the period between the Portland oolite and the gault—that period of partly marine, partly estuarine, and partly fresh-water strata, known as Purbeck, Wealden, and part of the lower greensand, approximately agreeing with the 'Neocomian' ages.

The fossil remains, when considered in relation to their proved or assumed places in geological time, give the following results as a first approximation. Very few specimens can be confidently declared to be known as resident in, or peculiar to, or characteristic of the lower greensand; some are found plentifully, even characteristically, though not exclusively, in the Wealden; one or two are on record from the Purbeck beds and the Portland rock; several from the Kimmeridge, and one or two from the Oxford clay. These statements are made on the evidence of specimens of my own procuring. From other sources[*] I collect similar results, though with some diversity, according to opportunities and varying personal views, especially as to the proportion of the fossils which may be regarded as truly of the age of the deposit.

Under what natural conditions could specimens from these various sources meet in this solitary and limited drift? In the Wealden we see the effects of downflowing land-streams; and, according to ordinary interpretation, the currents at last filled a large estuary. The river flowed and the rain-torrents swept over wasted surfaces of strata older than the Wealden, which yielded plenty of iron-oxide. But the typical Wealden beds contain no drifted fossils from older strata. The Potton sands must have had a similar origin—the waste of older land rich in oxide of iron—they may have been derived from the same land, but they require in addition a local action of a different kind, competent to yield quite different results. This action I believe to have been the beating of the sea on wasting cliffs of the Oxonian and Portlandian, perhaps also the older Wealden rocks.

To carry out this general view a very large extent of waste must be supposed to have happened on a range of coast where now extend the undulated surfaces north of the iron-sand ranges, for it seems reasonable to suppose the region to the south was deeper water for some not very considerable breadth on the northern slope of the ancient anticlinal of Harwich. It is possible indeed that such depth may not have there prevailed, and that from that side, on the contrary, came the ferruginous sediments, just as it may have happened that the similar Wealden sands and 'lower greensand' were derived from the southern slopes of the same anticlinal. It is not easy to obtain them by stream-action from the far north, and there is no sufficient reason yet established for admitting them to have come from the far west, the direction in which one is sometimes tempted to look for the local origin of all this thick mass of littoral, estuarine, and fluviatile sands.

While the Faringdon beds are full of the remains of resident life, or of marine creatures contemporaneous and vicinal, if not living on the spot where we find them, and the Shotover beds contain bands of fresh-water shells quietly deposited where they lived, the Potton sands and bone-bed, almost if not wholly heaped in agitated laminæ, are devoid of living residents, either of marine or fresh waters.

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[*] The literature of the Potton deposit is already extensive, including notices by Brodie, Walker, and Seeley in the Annals and Magazine of Natural History.

Though these beds may not have been quite contemporaneous—probably were not—they belong to one great system of physical events, connected with changes of level of sea and land. The oolites cease, and the clays connected with them; with them dies out a large group of marine life, and after them comes in a large and different series of rocks and fossils, constituting the true cretaceous system of Europe.

FOSSILS OF THE CRETACEOUS SYSTEM.

These have been as yet only partially collected in the country lying within the limits of Berks, Oxon, and Bucks, but abundantly in the region of Wiltshire, which therefore is included in the catalogue of localities. The lower greensand is exhibited in its most fossiliferous state at Faringdon, where shells and sponges which make up the greater part of the partially-aggregated mass have been collected by Austen, Morris, Sharpe, Wright, and other naturalists. The gault has been frequently explored from Oxford with moderate success at Culham; the upper greensand and chalk fossils must be quoted from Wiltshire, with hardly any important additions between that rich tract and the equally productive areas round Cambridge and West Norfolk. The palæontological differences between the several groups of strata here referred to are considerable, especially if we compare the series of lower greensand fossils with those of the chalk; but so much of analogy runs through the whole as to justify the combination of all into one general catalogue, such as that which follows. It is probable that the defect of localities for the chalk and upper greensand in the region south of Oxford may be remedied by repeated and more fortunate research on the part of the Geological Survey. Some species and localities derived from this source, principally supplied by Mr. Whitaker, are marked by the letters O. G. S.

The following abbreviations are employed:—

U. C.	Upper chalk.
L. C.	Lower chalk and chalk-marl.
U. G.	Upper greensand.
G.	Gault.
L. G.	Lower greensand.

FOSSILS OF THE CRETACEOUS SYSTEM.

PLANTS.

Confervites fasciculata. *Brongn.* U. C. Wilts.
Endogenous wood. L. C. Faringdon.
Strobilites Bucklandi. U. G. Wilts.

AMORPHOZOA.

Brachiolites labyrinthicus. *Mant.* U. C. Wilts.
Cephalites longitudinalis. *T. Smith.* U. C. Wilts.
„ subrotundus. *T. Smith.* U. C. Wilts.
Chenendopora complexa. *Benett.* U. G. Warminster.
„ expansa. *Benett.* U. C. Warminster.
„ fungiformis. *Lam.* L. G. Faringdon. U. G. Warminster.
„ obliqua. *Benett.* U. C. Wilts.
„ subplana. *Michel.* U. G. Pewsey.
„ undulata. *Benett.* U. G. Warminster.
Choanites Königi. *Mant.* U. C. Heytesbury.
Cnemidium astrophorum. *Mant.* L. G. Faringdon.
„ cepæforme. U. C. Warminster.
Coscinopora globularis. *Phil.* U. C. Warminster.
Hippalimus fungoides. *Lam.* U. G. Warminster.
Ierea Carteri. *Benett.* U. G. Warminster.
„ Desnoyeri. *D'Orb.* L. G. Faringdon.
„ pastinaca. *M'Coy.* U. G. Pewsey.
„ pyriformis. *Lam.* U. G. Warminster. L. G. Faringdon.
Manon Faringdonensis. *Sharpe.* L. G. Faringdon.
„ macropora. *Sharpe.* L. G. Faringdon.
„ marginatum. *Phil.* L. G. Faringdon.
„ peziza. *Goldf.* L. G. Faringdon.
„ porcatum. *Sharpe.* L. G. Faringdon.
„ pulvinarium. *Goldf.* L. G. Faringdon.
Plocoscyphia meandroides. *Leym.* U. G. Wilts.
„ morchella. *Goldf.* U. G. Wilts.
Polypothecia dichotoma. *Benett.* U. G. Warminster.
„ fissa. *Benett.* U. C. Wiley, Wilts.
„ gregarea. *Benett.* U. G. Warminster.
„ infundibuliformis. *Benett.* U. C. Pertwood, Wilts.
„ palmata. *Benett.* U. C. Wiley.
Scyphia foraminosa. *Goldf.* L. G. Faringdon.
„ furcata. *Goldf.* L. G. Faringdon.
„ infundibuliformis. *Goldf.* L. G. Faringdon.
„ intermedia. *Mant.* L. G. Faringdon.
„ mammillaris. *Goldf.* L. G. Faringdon.

Siphonia costata. *Lam.* U. G. Warminster.
,, pyriformis. *Goldf.* U. G. Warminster.
Spongia Michelinii. *Reuss.* L. G. Faringdon.
,, multidigitata. *Michel.* L. G. Faringdon.
,, ramosa. *Mant.* U. C. Wilts.
,, Trigeris. *Michel.* L. G. Faringdon.
Ventriculites alcyonoïdes. *Mant.* U. C. Wilts.
,, alternans. *Röm.* U. C. Wilts.
,, bicomplicatus. *O. G. S.* U. C. Wilts.
,, flexuosus. *Mant.* U. C. Wilts.
,, radiatus. *Mant.* U. C. Wilts.
,, Townsendi. *Mant.* U. C. Wilts.
Verticillites anastomosans. *Mant.* L. G. Faringdon.

The extraordinary number of spongiform fossils in the cretaceous system is accompanied by circumstances of much local diversity. The Faringdon gravel deposits shew limited local drift, or merely displacement; the Warminster sand-beds indicate greater distance from shore; and the chalk fossils probably grew in deeper and more tranquil waters, such as lately yielded to Dr. Carpenter and Prof. W. Thomson flinty analogues, still living in the Atlantic, of the old cretaceous amorphozoa.

FORAMINIFERA.
Cristellaria rotulata. *Lam.* L. G. Faringdon. U. G. Warminster.
Guttulena. sp. L. G. Faringdon.
Nodosaria obscura. *Reuss.* U. G. Warminster.
Truncatulina. sp. U. G. Warminster.

ACTINOZOA.
Micrabacia coronula. *Goldf.* U. G. Warminster.
Parasmilia cultrata. *Lonsd.* U. C. Wilts.

ECHINODERMATA.
Echinoidea.
Ananchytes ovatus. *Leske.* U. C. Wilts. Tilehurst, near Reading.
,, lævis. *Deluc.* U. G. Wilts.
,, pilula. *Lam.* U. C. Wilts.
,, subglobosus. *Leske.* L. C. Wilts.
Caratomus rostratus. *Ag.* U. G. Warminster.
Cardiaster fossarius. *Benett.* U. G. Warminster.
,, grandis. *Benett.* U. C. Wilts.
Catopygus carinatus. *Goldf.* U. G. Warminster. U. C. Maiden-Bradley.
Cidaris arenicola. *O. G. S.* U. G. Warminster.
,, clavigera. *Kön.* U. C. Wilts.
,, Faringdonensis. *Wr.* L. G. Faringdon.
,, insignis. *Gras.* U. G. Warminster.
,, sceptrifera. *Mant.* U. C. Wilts.
,, velifera. *Bronn.* U. G. Devizes.
,, vesiculosa. *Goldf.* U. C. Wilts.

Cyphosoma Königi. *Mant.* U. C. Wilts.
„ M'Coyi. *O. G. S.* U. G. Warminster.
„ rotula. *O. G. S.* U. G. Warminster.
Diadema Benettiæ. *Forbes.* U. G. Warminster.
„ Bonei. *Forbes.* U. G. Warminster.
„ Brongniarti. *Ag.* L. C. Maiden-Bradley.
„ difficilis. *Wright.* U. G. Warminster.
„ M'Coyi. *Forbes.* U. G. Warminster.
„ ornatum. *Goldf.* U. G. Wilts.
„ Rhodani. *Ag.* U. G. Warminster. L. G. Faringdon.
„ rotulare. *Ag.* L. G. Faringdon, Seend.
„ subnudum. *Ag.* U. G. Warminster.
„ variolare. *Ag.* U. G. Warminster. L. G. Faringdon.
Discoidea subuculus. *Leske.* U. G. Warminster.
Echinus granulosus. *Munst.* U. G. Warminster.
Galerites abbreviatus. *Lam.* U. C. Wilts.
„ albogalerus. *Lam.* U. C. Wilts, Oxon.
„ castaneus. *Breyn.* U. G. Warminster.
Goniopygus peltatus. *Ag.* U. G. Warminster. L. G. Faringdon.
Micraster coranguinum. *Leske.* U. C. Wilts.
Nucleolites cordatus. *Goldf.* U. G. Warminster.
„ lacunosus. *Goldf.* U. G. Warminster.
„ Morrisii. *Forbes.* U. G. Warminster.
Salenia clathrata. *Ag.* U. G. Warminster.
„ gibba. *Ag.* U. G. Warminster.
„ granulosa. *Forbes.* U. C. Warminster.
„ Lardyi. *Desor.* L. G. Faringdon.
„ lunulata. *Ag.* U. G. Warminster.
„ petallifera. *Defr.* U. G. Warminster.
„ stellulata. *Ag.* U. G. Warminster.
„ umbrella. *Ag.* U. G. Warminster.
„ Wrightii. *Desor.* L. G. Faringdon.
Trematopygus Faringdonensis. *Wr.* L. G. Faringdon.

Asteroidea.

Goniaster lunatus. *Woodw.* U. C. Wilts.
„ rugatus. *Forbes.* U. C. Wilts.
„ uncatus. *Forbes.* U. C. Wilts.
Oreaster pistilliformis. *Forbes.* U. C. Wilts.

Crinoidea.

Bourguetocrinus ellipticus. *Miller.* U. C. Wilts.

This list exhibits in a striking manner the great change which has occurred in the echinodermatal groups, as compared with the oolites, in which ananchytes, cardiaster, and micraster have no place, and diadema, galerites, and salenia are very rare, if they occur at all[f].

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[f] In Dr. Wright's Monograph of Cretaceous Echinida, now in progress, Diadema and Salenia are somewhat reduced by transfer of species to genera constructed since Agassiz gave his classification.

ANNELLIDA.

Serpula antiquata. *Sow.* U. G. Wilts.
„ gordialis. *Schl.* L. G. Faringdon.
„ obtusa. *Sow.* L. G. Faringdon.
„ plana. *Woodw.* U. G. Warminster.
„ plexus. *Sow.* U. G. Wilts.
„ quinquecostata. *Röm.* L. G. Faringdon.
Vermicularia concava. *Sow.* U. G. Devizes.
„ umbonata. *Sow.* U. G. Wilts.

CRUSTACEA.

Bairdia siliqua. *Jones.* U. C. Wilts. -
„ subdeltoidea. *Munst.* U. G. Warminster.
„ triquetra. *Jones.* U. G. Warminster.
Cythere Bairdiana. *Jones.* L. G. Faringdon.
„ punctatula. *Röm.* U. G. Warminster.
Cythereis ciliata. *Reuss.* U. G. Warminster.
„ interrupta. *Bosq.* U. G. Wilts.
Cytherella ovata. *Röm.* U. G. Warminster.
Neocarcinus Buhli. *O. G. S.* U. G. Warminster.

POLYZOA.

Actinopora papyracea. *D'Orb.* L. G. Faringdon.
Alecto Calypso. *D'Orb.* L. G. Faringdon.
„ gracilis. *Edw.* U. G. Wilts.
„ ramea. *D'Orb.* L. G. Faringdon.
Ceriocava irregularis. *D'Orb.* L. G. Faringdon.
„ ramulosa. *D'Orb.* L. G. Faringdon.
Ceriopora mammillosa. *D'Orb.* L. G. Faringdon.
„ polymorpha. *Goldf.* L. G. Faringdon.
„ venosa. *Goldf.* L. G. Faringdon.
Cricopora gracilis. *Goldf.* U. G. Warminster.
Diastopora clavula. *D'Orb.* L. G. Faringdon.
„ congesta. *D'Orb.* L. G. Faringdon.
„ oceanica. *D'Orb.* L. G. Faringdon.
„ papyracea. *D'Orb.* L. G. Faringdon.
„ ramea. *Dixon.* L. G. Faringdon.
„ ramulosa. *Michel.* L. G. Faringdon.
„ spongiosa. *D'Orb.* L. G. Faringdon.
„ tuberosa. *D'Orb.* L. G. Faringdon.
Domopora clavula. *D'Orb.* L. G. Faringdon.
„ tuberculata. *D'Orb.* L. G. Faringdon. U. G. Warminster.
Entalophora Cenomana. *D'Orb.* L. G. Faringdon.
„ costata. *D'Orb.* L. G. Faringdon.
„ Meudonensis. *D'Orb.* L. G. Faringdon.
„ ramosissima. *D'Orb.* L. G. Faringdon.
„ Sarthacensis. *D'Orb.* L. G. Faringdon.
Heteropora cryptopora. *Goldf.* L. G. Faringdon.
„ dichotoma. *Goldf.* L. G. Faringdon.
Laterocavea punctata. *D'Orb.* L. G. Faringdon.
Lopholepis Hagenovii. *Sharpe.* L. G. Faringdon.

Lunulites cretaceus. *Defr.* U. C. Wilts.
Multicavea lateralis. *D'Orb.* L. G. Faringdon.
Multicrescis mammillata. *D'Orb.* L. G. Faringdon.
„ variabilis. *D'Orb.* L. G. Faringdon.
Nodelea semiluna. *D'Orb.* L. G. Faringdon.
Petalopora pulchella. *Röm.* U. C. Wilts.
Proboscina marginata. *D'Orb.* L. G. Faringdon.
„ subelegans. *D'Orb.* L. G. Faringdon.
Pustulopora pseudospiralis. *Michel.* L. G. Faringdon.
Radiopora pustulosa. *D'Orb.* L. G. Faringdon.
Reptocea Cenomana. *D'Orb.* L. G. Faringdon.
Reptocollis mammilla. *D'Orb.* L. G. Faringdon.
„ micropora. *D'Orb.* L. G. Faringdon.
„ multicava. *D'Orb.* L. G. Faringdon.
Reptotubigera elevata. *D'Orb.* L. G. Faringdon.
„ marginata. *D'Orb.* L. G. Faringdon.
„ ramosa. *D'Orb.* L. G. Faringdon.
Semimultea irregularis. *D'Orb.* L. G. Faringdon.
Zonopora undata. *D'Orb.* L. G. Faringdon.
„ variabilis. *D'Orb.* L. G. Faringdon.

These beautiful objects are mostly in fragments, and difficult to discriminate specifically: it is likely that some which vary in aspect, according as the specimens are taken from stems or branches, may have been counted twice. The general fact of their great numerical prevalence remains, and is one of the points of resemblance to the fossils of the upper chalk and the lower crag.

BRACHIOPODA.

Argiope Buchii. *Hagenow.* U. C. Pewsey, Wilts.
„ megatrema. *Sow.* U. G. Warminster.
Crania Cenomanensis. *D'Orb.* L. G. Faringdon.
„ Parisiensis. *Defr.* L. G. Faringdon.
Lingula subovalis. *Dav.* U. G. Warminster.
Rhynchonella antidichotoma. *Buv.* L. G. Faringdon.
„ compressa. *Lam.* U. G. Warminster.
„ depressa. *Sow.* L. G. Faringdon.
„ Grasiana. *D'Orb.* U. G. Warminster.
„ latissima. *Sow.* U. G. Warminster. L. G. Faringdon.
„ nuciformis. *Sow.* L. G. Faringdon.
„ octoplicata. *Sow.* U. C. Wilts.
„ triangularis. *Wahl.* L. G. Faringdon.
Terebratella lima. *Defr.* U. G. Wilts.
„ lyra. *Sow.* U. G. Warminster.
„ Menardi. *Lam.* L. G. Seend, Faringdon.
„ pectita. *Sow.* U. G. Warminster.
Terebratula biplicata. *Sow.* U. G. Wilts.
„ Boubei. *D'Arch.* L. G. Faringdon.
„ depressa. *Lam.* L. G. Faringdon.

Terebratula Gibbsiana. *Sow.* L. G. Seend.
„ Keyserlingii. *D'Arch.* L. G. Faringdon.
„ lachrymosa. *D'Orb.* U. G. Warminster.
„ Nerviensis. *D'Arch.* L. G. Faringdon.
„ nuciformis. *Sow.* L. G. Seend.
„ obesa. *Sow.* L. C. Norton-Bavant. U. G. Warminster.
„ oblonga. *Sow.* L. G. Faringdon.
„ ovata. *Sow.* U. G. Warminster.
„ revoluta. *D'Arch.* L. G. Faringdon.
„ Robertoni. *D'Arch.* L. G. Faringdon.
„ Römeri. *D'Arch.* L. G. Faringdon, Seend.
„ sella. *Sow.* L. G. Seend.
„ semiglobosa. *Sow.* L. C. Wilts.
„ squamosa. *Mant.* U. G. Devizes.
„ sulcifera. *Dav.* and *Mor.* L. C. Wilts.
„ tamarindus. *Sow.* L. G. Faringdon, Seend.
Terebratulina striata. *Wahl.* U. G. Warminster.
Thecidium Wetherelli. *Mor.* U. C. Pewsey, Wilts. L. G. Faringdon.

The groups of rhynchonella and terebratula are now found to deviate from the ordinary patterns of the oolite in the direction of the living Rhynchonella psittacea and Terebratula vitrea; and terebratella assumes importance. The Faringdon deposit is, in respect of the brachiopoda, much richer than the average of lower greensand.

MONOMYARIA.
Avicula lineata. *Röm.* L. G. Faringdon.
Dianchora striata. *Sow.* U. G. Warminster. L. G. Faringdon.
„ radiata. *Goldf.* L. G. Faringdon.
„ guttata. *Sharpe.* L. G. Faringdon.
Exogyra conica. *Sow.* L. G. Faringdon. U. G. Warminster.
„ haliotidea. *Sow.* U. G. Warminster.
Gryphæa vesiculosa. *Sow.* U. G. Wilts.
Inoceramus concentricus. *Sow.* U. G. Warminster. G. Warminster.
„ cuneiformis. *O. G. S.* U. G. Warminster.
„ Lamarckii. *Park.* U. C. Wilts.
„ mytilloides. *Mant.* L. C. Warminster. U. G. Warminster.
„ striatus. *Mant.* L. C. Heytesbury.
„ sulcatus. *Sow.* G. Wilts, Culham.
Lima Cenomanensis. *O. G. S.* U. G. Warminster.
„ consobrina. *D'Orb.* L. G. Faringdon.
„ dichotoma. *Reuss.* L. G. Faringdon.
„ Faringdonensis. *Sharpe.* L. G. Faringdon.
„ multicostata. *Reuss.* L. G. Faringdon.
„ ornata. *D'Orb.* U. G. Warminster.
„ semiornata. *D'Orb.* U. G. Warminster
„ simplex. *D'Orb.* U. G. Warminster.

Ostrea canaliculata. *Sow.* U. G. Warminster.
  „ frons. *Park.* U. G. Warminster.
  „ macroptera. *Sow.* G. Culham. L. G. Faringdon.
  „ Normanniana. *D'Orb.* U. G. Warminster.
  „ semiplana. *Mant.* U. C. Wilts.
  „ vesicularis. *Lam.* U. G. Warminster.
Pecten æquicostatus. *Lam.* U. G. Warminster.
  „ asper. *Lam.* U. G. Warminster.
  „ atavus. *Röm.* U. G. Warminster.
  „ Beaveri. *Sow.* L. C. Wilts, Pangbourn.
  „ Dutemplii. *D'Orb.* L. G. Faringdon.
  „ elongatus. *Lam.* G. and U. G. Warminster.
  „ interstriatus. *Leym.* L. G. Faringdon, Seend.
  „ nitidus. *Mant.* U. C. Wilts.
  „ orbicularis. *Sow.* U. G. Devizes.
  „ quadricostatus. *Sow.* U. G. Warminster.
  „ quinquecostatus. *Sow.* U. G. Warminster.
  „ Raulinianus. *D'Orb.* L. G. Faringdon.
  „ striato-costatus. *Goldf.* L. G. Faringdon. U. G. Warminster.
Pinna Galliennei. *D'Orb.* U. G. Warminster.
  „ Moreana. *D'Orb.* U. G. Warminster.
Plicatula inæquidens. *Sharpe.* L. G. Faringdon.
Spondylus spinosus. *Sow.* U. C. Wilts.
  „ striatus. *Sow.* U. G. Warminster.

Few genera but rich in species are recognized among cretaceous monomyaria. Exogyra, a frequent and characteristic genus of lower cretaceous fossils, can be fairly quoted from the Portland, if not Coralline, oolite.

Spondylus spinosus has changed more than once its generic title; dianchora makes its appearance, and for inoceramus this series of rocks is the capital.

DIMYARIA.

Anatina. sp. U. G. Warminster.
Arca carinata. *Sow.* U. G. Devizes.
  „ Carteroni. *O. G. S.* L. G. Coleshill.
  „ Marcellensis. *D'Orb.* L. G. Faringdon.
Astarte transversa. *O. G. S.* L. G. Faringdon, Coleshill.
Cardium Gentianum. *Sow.* U. G. Devizes.
  „ Ibbetsoni. *O. G. S.* L. G. Devizes.
  „ Michelini. *D'Arch.* L. G. Faringdon.
  „ subhillanum. *Leym.* L. G. Devizes.
Corbula. sp. L. G. Seend.
Cucullæa. sp. U. G. Devizes. L. G. Faringdon.
Cyprina oblonga. *O. G. S.* U. G. Devizes.
Cytherea parva. *Sow.* G. Wilts.
Diceras Lonsdalii. *O. G. S.* L. G. Devizes.

Lithodomus. sp. U. G. Warminster.
Lucina Dupiniana. *O. G. S.* U. G. Devizes.
Modiola. sp. U. G. Devizes. L. G. Seend.
Myacites mandibula. *Sow.* U. G. Devizes.
Mytilus siliqua. *O. G. S.* U. G. Devizes.
Nucula impressa. *O. G. S.* L. G. Devizes.
Opis Coquandiana. *D'Orb.* L. G. Seend.
„ neocomiensis. *D'Orb.* L. G. Seend.
Pectunculus. sp.* L. G. Faringdon.
„ umbonatus. *Sow.* G. Ridge, Wilts.
Pholadomya decussata. *Phil.* L. C. Pangbourn.
„ Mailleana. *D'Orb.* U. G. Warminster.
Tellina inæqualis. *Sow.* U. G. Devizes.
Thetis major. *Sow.* U. G. Devizes.
„ minor. *Sow.* L. G. Wilts.
Trigonia spinosa. *Sow.* U. G. Devizes.
Unicardium Ringmeriense. *O. G. S.* U. G. Devizes.

This list, probably very incomplete as to species, exhibits a large enough series of genera to justify the remark of the greater affinity of the dimyarian families in the greensand to those of the oolites, than is to be found on comparing the lower and upper parts of the cretaceous system of strata. The reason is obvious—the sandy groups of the lower cretaceous rocks were in a considerable degree of littoral origin; the chalk was formed in deeper and quieter water farther from shore.

GASTEROPODA.

Acmæa tenuicosta. U. G. Devizes.
Emarginula Guerangeri. *D'Orb.* L. C. Wilts.
„ neocomiensis. *D'Orb.* L. G. Seend.
Natica cretacea. *O. G. S.* U. G. Devizes.
„ Gentii. *Sow.* U. G. Devizes.
„ nodosa. *Gein.* L. G. Faringdon.
Pleurotomaria perspectiva. *Mant.* L. C. Tetsworth. U. C. Warminster.
Pterocera bicarinata. *Desh.* U. G. Devizes.
Solarium conoideum. *Sow.* G. Vale of Wardour.
Turritella granulata. *Sow.* U. G. Vale of Wardour, Warminster.
Vermetus. U. G. Warminster.

Holostomatous gasteropods of oolitic genera still prevail, and carry on the mesozoic life toward the tertiary period, when the other great group of siphonostomata begins to contend for numerical superiority.

CEPHALOPODA.

Ammonites auritus. *Sow.* U. G. Devizes.
„ Bendantii. *Brong.* G. Vale of Wardour.

Ammonites Catinus. *Mant.* L. C. Devizes.
„ Cunningtoni. *Sharpe.* L. C. Devizes.
„ falcatus. *Mant.* L. C. Wilts.
„ mammillaris. *Schl.* U. G. Crockerton, Wilts.
„ navicularis. *O. G. S.* L. C. Devizes.
„ nutfieldiensis. *Sow.* L. G. Seend.
„ peramplus. *Mant.* L. C. Wilts.
„ rostratus. *Sow.* U. G. Devizes. L. C. Warminster.
„ serratus. *Park.* G. Warminster, Culham.
„ splendens. *Sow.* G. Warminster, Culham.
„ Sussexiensis. *Mant.* L. C. Wilts, Basset Down, Cholsey, Berks.

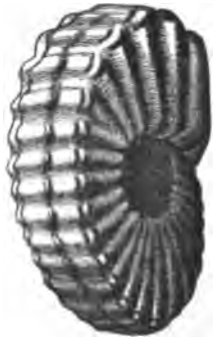
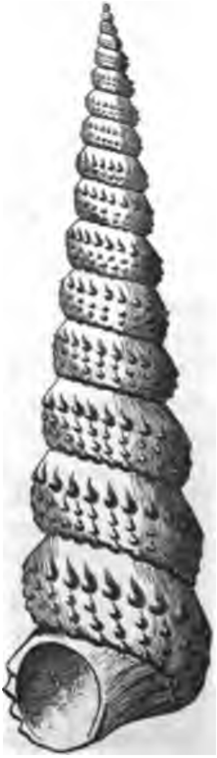


Diagram CXCVII. Ammonites Sussexiensis.



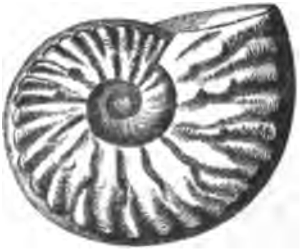


Diagram CXCVIII. Ammonites varians.

Diagram CXCIX. Turrilites tuberculatus.

Ammonites varians. *Sow.* L. C. Wilts. U. G. Warminster, Cholsey, Berks.
„ Velledæ. *O. G. S.* G. Wilts.
Baculites. U. C. Herts.
Belemnitella minima. *List.* G. Wilts.
„ mucronata. *Schl.* U. C. Wilts.
„ plena. *Blainv.* L. C. Wilts.

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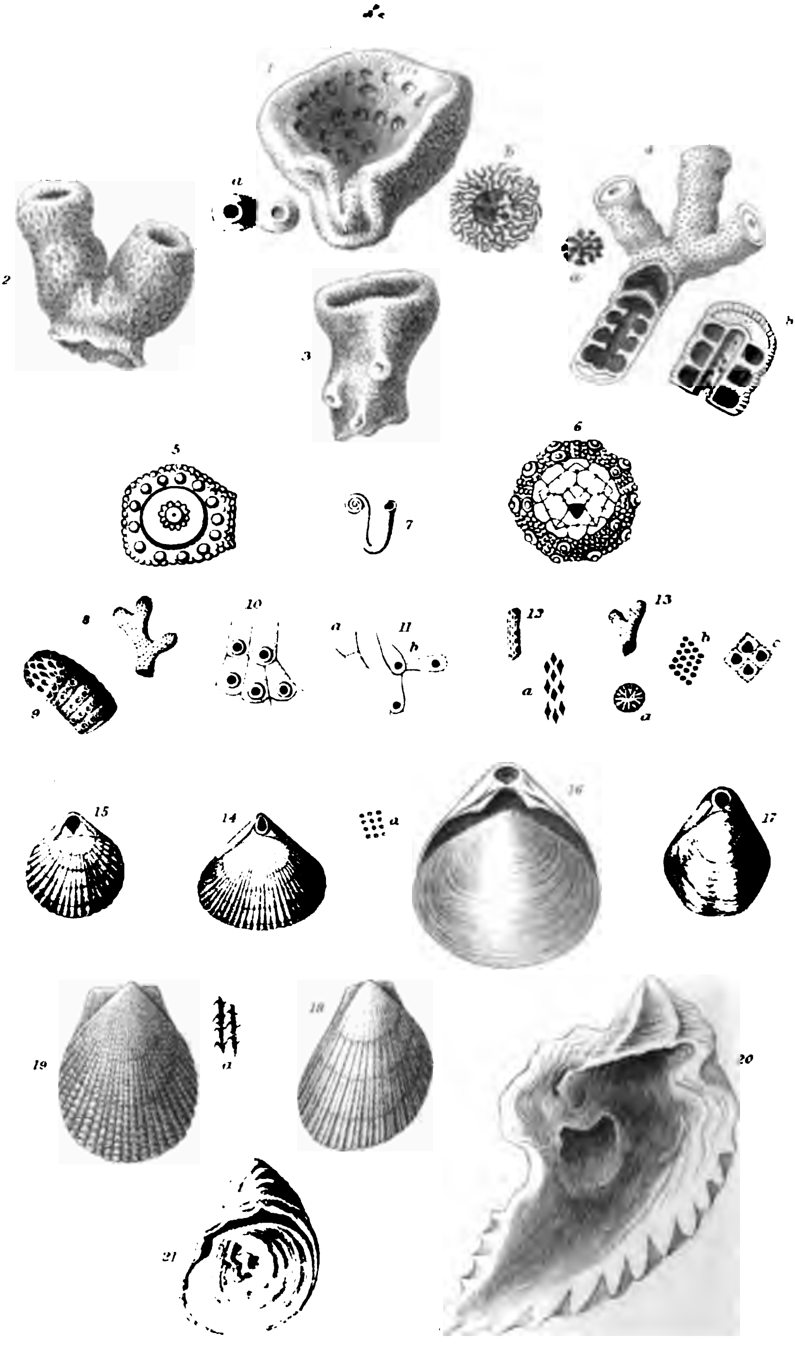
LOWER GREEN SAND.



Drawn by J. P.

Hamites armatus. *Sow.* L. C. Basset-Down, Wilts.
„ attenuatus. *Sow.* G. Wilts.
„ Parkinsoni. *Flem.* U. G. Wilts.
Nautilus Deslongchampianus. *O. G. S.* L. G. Warminster.
„ elegans. *Sow.* U. G. Warminster.
„ Faringdonensis. *Sharpe.* L. G. Faringdon.
„ lævigatus. *D'Orb.* L. G. Faringdon. L. C. Warminster.
„ Larzilliertianus. *O. G. S.* L. C. Warminster.
„ pseudelegans. *D'Orb.* U. G. Devizes.
Scaphites æqualis. U. C. Herts.
Turrilites Scheuzerianus. *Bosc.* L. C. Wilts.
„ tuberculatus. *Sow.* L. C. Basset-Down, Wilts.

Belemnitella comes now for the first time into notice, and replaces the older type of belemnites. Hamites becomes prevalent, and with scaphites, baculites, and turrilites give quite a new aspect to the group of the ammonitidæ.

PISCES.
Placoidei.
Acrodus.
Gyrodus. *O. G. S.* L. G. Faringdon.
Lamna acuminata. *Ag.* L. G. Faringdon.
Otodus appendiculatus. *Ag.* U. G. Warminster.
Pycnodus. *O. G. S.* L. G. Faringdon.
Strophodus. *O. G. S.* L. G. Faringdon.
REPTILIA. None obtained in this district.

REFERENCE TO THE FIGURES OF FOSSILS FROM THE LOWER GREENSAND ('SPONGE-BED') OF FARINGDON IN PLATE XVII.

1. Manon macropora, ordinary appearance. *a.* The oscula, when the surface is seen complete. *b.* The same decorticated.
2, 3. Manon Faringdonensis.
4. Verticillites anastomosans. *a.* The surface magnified. *b.* Section of the interior.
5. Cidaris Faringdonensis. One plate.
6. Salenia punctata.
7. Serpula gordialis.
8. Pustulopora pseudospiralis.
9. The same, magnified.
10. Diastopora ramea (?), magnified.
11. Alecto gracilis, magnified.
12. Cricopora gracilis. *a.* Magnified cells.
13. Ceriopora dichotoma. *a.* Cross section. *b.* Magnified cells. *c.* Still more magnified.
14. Rhynchonella latissima.
15. Terebratella Menardi.
16. Terebratula depressa. *a.* The pores.
17. „ Tornacensis.
18. Lima Faringdonensis.
19. Pecten elongatus. *a.* The plaits.
20. Ostrea frons.
21. Exogyra conica.

These fossils are regarded as inhabitants of the waters in which the sponge-beds were deposited; others drifted into this deposit, from older strata, are mentioned p. 425.

CHAPTER XVII.

EOCENE PERIOD.

After a long interval of time the great chalk deposit, partly raised from the sea-bed, so as with the older oolites to shape out in some degree the boundaries of a broad sea-loch, where now flows the Thames, was covered by sediments of the cainozoic period, to which Lyell gave the title of Eocene strata. Before this happened the surface of the chalk was wasted, in the district near Reading literally ground down in some places to a plane or undulated surface, as it is this day on some parts of the Yorkshire coast; and from this worn surface to the depth of a foot, in various directions the rock was bored, drilled we may say, by 'lithodomous' bivalves, much as happens to the chalk below the cliffs of Flamborough. The holes are filled by the dark eocene sands which were the earliest deposits to follow.

This curious phænomenon may be very well studied at Theale, near Reading, where a small chalk pit occasionally allows the upper layer to project and shew its under surface, so that the holes may be examined both in the vertical and horizontal aspects.

For considerable spaces round Reading the chalk is in this manner covered uniformly by sands and clays of different tints and thicknesses; in some cases they are not only undulated, but sink into hollows, pits, or pipes in the chalk. These pits and hollows are of subsequent date; they are mostly the effect of atmospheric water, which, by dissolving the chalk in particular lines more than elsewhere and carrying it downwards, has caused a gradual sinking of small spaces, in which the eocene beds form curves more or less conformed to the walls of the cavity in the chalk. This is a common phænomenon in the regions of the English chalk.

Another curious mark of the proximity of this old chalk surface to the level of the sea at the time of the beginning of the eocene deposits, is a bed of oyster shells lying on the chalk. These shells (O. bellovacina) have been long known and often considered since Dr. Plot, in his Natural History of Oxfordshire, suggested that those found in abundance at 'Cat's-grove' (now Katesgrove) near Reading may be the reliquiæ of oysters supplied for food by the Danish navy while the army held a fortified post at the junction of the Kennet and Thames.

Among important memoirs on the cainozoic deposits near Reading, may be mentioned Dr. Buckland's notices of the section at Katesgrove; Mr. Prestwich's comprehensive Essay on the Lower Eocene Beds in the whole Basin of the Thames; Professor Jones's Notices of the country about Newbury; and Mr. Whitaker's Memoir on the Geological Map of the district.

Only the lower portions of this great system of strata appear in the south-eastern slopes of the chalk ranges of Wilts, Berks, Bucks, and Beds. Among these the 'Sarsen' stone, which lies in the chalk valleys near Marlborough, the 'Pudding-stone' of St. Albans, and the oyster beds and other shelly layers at Reading, may be remarked as among the most interesting.

The highest points of land occupied by any of the cainozoic strata within the area embraced in the General Map, Plate I., are on the line of the old coach road over the Chiltern Hills, at Nuffield, 696, and Nettlebed, 692 feet above the mean sea-level. From these and other elevations at many points, but not over large surfaces, the eocene beds are noticed in descending from the downs of Herts, Oxon, and Berks toward the Thames and the Kennet, and they give favourable sites for a considerable number of thickets and woods which are rarely seen on the less genial and drier chalk.

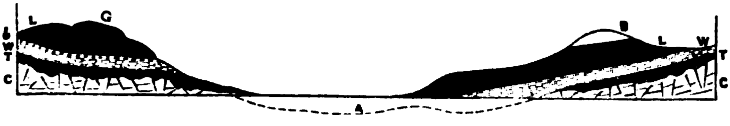


Diagram CC. Eocene beds in the Vale of Thames.

C. Chalk. T. Thanet sand. W. Woolwich beds. *b.* Blackheath pebbles.

L. London clay. B. Bagshot beds. G. Gravel.

In a general view, the cainozoic beds of marine origin in the vale or basin of the Thames belong mainly to the earlier or eocene group: the meiocene and pleiocene strata (taking this last to include all the successive 'crag' beds) are deficient. After a long interval we find glacial, marine, and fresh-water deposits, of the pleistocene age, to which the next chapter is devoted.

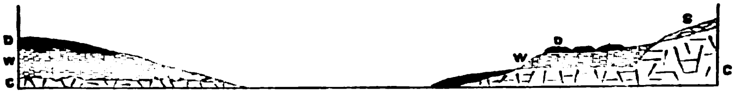


Diagram CCI. Section across the Vale of Kennet.
C. Chalk. W. Woolwich beds. S. Sarsen stone. D. Drift.

The best sections of these strata which fall within the area of the Map already referred to are found near Reading.

At Theale the following succession is clearly seen:—

	ft.	in.
g. The soil slightly mixed with pebbles of flint, with a few fragments of red quartzite and other northern stones	2	6
f. Clay not laminated, penetrated by tubular traces of plant roots . .	1	6
e. Yellow sand, of coarse grain with very small chips of flint (marten holes)	1	6
d. Pale laminated clays	1	6
c. Pale and brown laminated clay bands	2	6
b. Ferruginons laminated bands	1	6
a. Brown bands, pebbly above, and again at the base pebbly and dark, with Ostrea bellovacina	2	0

Beneath is chalk perforated in various directions to the depth of a foot; and below this, chalk with flints in irregular layers with variously directed joints. Here occurs Ananchytes ovatus.

The series at Katesgrove, near Reading, examined by Dr. Buckland[a] in 1817, may be thus described:—

	ft.
Surface deposit of clay, sand, and gravel; this last composed of chalk, flint, quartz, and brown compact sandstone.	
Loamy sand and clay, ferruginous below	11
Clay, dark-red and mottled with grey	4
Clay, ash-coloured, and fine sand of same tint	7
Sand, micaceous, laminated, and partially mixed with clay	4

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[a] Geol. Trans., vol. iv. p. 276 (1817).

	ft.
'White vein'—sand with some ash-coloured clay	5
Clay, dark-red, mottled with blue	6
Brick-clay—light-grey with fine sand	5
White sand	4
Fuller's-earth	3
Sand, quartzose, yellowish	5
Sand with green earth, chalk flints, green-coated. *Ostrea bellovacina, fish-teeth*	3
Chalk with flints, drilled with tubular holes	unknown

Several of the beds of clay are partially ironshot.

Since the publication of Dr. Buckland's section of the clays and sands which cover the chalk on the bank of the river at Katesgrove, close to Reading, the excavations have been carried farther into the hill, which in the upper part now shews bands of shells, perhaps forming the basement beds of the London clay.

In these upper shell beds M. Rofe[b] found—

Cytherea incrassata.
Pectunculus breviformis.
Modiola elegans.
Dentalium planum.
Ampullaria sigaretina.

And in the oyster bed at the base of the eocene—

Ostrea Bellovacina.
„ pulchra.
„ tener.

The railway cuttings near Reading furnished good sections, including the sands and mottled clays which lie over the beds already noticed at Theale. One of these at Sonning Hill[c] presents a considerable thickness.

	ft.	in.
Subangular flint gravel, ochreous, average	12	0
Basement bed of the London clay, fossiliferous brown clay with yellow and green sand, pebbles, and septaria	5	0
Mottled, bluish, red, and grey clay	10	0
Sand irregular, yellow or grey	2	0
Mottled, brown, and blue clay	23	0
Dark grey clay		
Mottled, red, and grey clay		

[b] Geol. Trans., 2nd Series, vol. v. p. 130.

[c] Prestwich in Geol. Proceedings, 1853.

		ft.	in.
Sand, white, irregular		2	6
Red clay		1	6
Light grey clay		0	6
Very dark grey clay		6	0
Red clay		2	0
Light grey clay		1	0
Sand, yellow, with bands of brown clay		2	0
Dark clay	not exposed in the cutting	10	0
Sand, ash coloured		5	0
Green-coated flints		1	0
Under this the chalk.			

Mr. Prestwich gives also an excellent section at Clayhill, Newbury, which in general range matches that at Sonning Hill:—

	ft.
Basement bed of the London clay, consisting of brown clay and traces of shells	10
Mottled, red, and bluish clay	15
White sand	1
Mottled clay	10
Sands and loam	10 ?
Light-coloured and ochreous sand, laminated	3
Clay dark grey, laminated, sand grey and green, and a few pebbles	8
The same, with Ostrea bellovacina	1
Clay dark grey, with greensand; no oysters	2
The same, with oysters, teeth, &c., pebbly	1
The same, with pebbles and a few unrolled flints	1
Chalk, with tubular perforations filled with greensand	20

In these sections no mention is made of the well-known 'Druid' sandstone of Wiltshire, or of the flinty pudding-stone of Hertfordshire. Sands of greater thickness occur in other excavations, usually under the mottled clays, and it is very conceivable that they may elsewhere be represented by hard sandstones, as some of the pebbly sands may have become converted into siliceous pudding-stone. In this way perhaps we may account for the 'Druid' sandstones, or 'Grey Weathers,' or 'Sarsen' stones, which lie in such abundance about Ashdown in the Berkshire valleys, and between Marlborough and Avebury in those of Wiltshire. They lie at present for the most part in much confusion; but it is not difficult to perceive that they are parts of a more extensive stratum, once deposited unconformably in the *previously excavated valley* of chalk. The loose sands in which these masses were concretionary, and yet stratified, have been carried away, and the solid parts have suffered some displacement.

I have never found shells in any of these stones lying in their native beds, and have some scruple in mentioning that they do occur in a layer in one of the blocks at Stonehenge. But as I did not choose by chiselling that monumental stone to attract attention to it, probably it may for many years to come escape all injury except that which it must suffer from the strokes of time.

The result of a careful inquiry by Mr. Prestwich was to convince him that the 'Sarsen' stones belong to the lower eocene series of Woolwich and Reading; but Mr. Whitaker, who has found a thin deposit of true London clay in the Vale of Kennet, prefers to class them as part of the Bagshot sands.

It is worth remarking in connection with the 'Sarsen' stones, that drifted-masses which seem to correspond with them (having occasionally flint pebbles and siliceous fragments imbedded) lie on the north side of the Wiltshire downs, near Swindon, and that a fragment of the sandstone of considerable size was found in post-glacial drift as far north as the Thames at Long Wittenham, near Abingdon.

To complete our view of the eocene strata in the basin of the Thames, by including a portion of the higher beds, we must go down stream. London and the immediate vicinity offers to inspection, in pits, wells, road and railway-cuttings, the whole series up to the Bagshot sands, and down to the Thanet sands, which are supposed not to extend westward into the district round Reading. On Mr. Mylne's excellent Map[d], and in his authentic sections, the course of all these strata can be clearly traced, and their general relations to the chalk and its large supply of water satisfactorily studied. Mr. Prestwich, in several remarkable memoirs presented to the Geological Society, has furnished full descriptions of the strata, their thicknesses and distribution, and catalogues of the fossils they contain[e].

The following is a very condensed view or general index to the whole of the early cainozoic series in the lower part of the Vale of the Thames.

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[d] Geological Map of London and its Environs, by R. W. Mylne, F.R.S., F.G.S. (1871).

[e] Consult Journal of the Geological Society, vols. iii., vi., viii., and x.

Thanet Sand, the lowest of all the groups, is little seen except in the lower course of the Thames, where it is traceable from London downward to the district from which it derives its name. It is, however, discovered in wells under the Woolwich beds, in a considerable tract west and north of London, seldom more than 50 feet thick. It is a light-coloured sand, with very slight trace of mica, and very little carbonate of lime; and only near the base mixed with any sensible proportion of argillaceous matter. At the base it is often greenish, and almost always holds (or is almost composed of) chalk flints of various magnitude, sometimes extremely large, not much worn by attrition, but often stained with a permanent green tint on the surface. The fossils found in several situations, as Reculver, Pegwell Bay, and Richborough, are mostly shells, and all marine.

The Woolwich and Reading series of sands, and mottled and laminated clays, with fluviatile, estuarine, and marine shells, succeeds and forms a narrow belt on the south side of the Thames above the Thanet sands, about 50 feet thick. The fossil shells lie in bands, and are on the whole estuarine, or a mixture or alternation of truly marine and truly fresh-water mollusca. The genera Cyrena, Cardium, Melanopsis, and Cerithium, with Ostrea bellovacina, are common. In the great pit south of Erith, at the base of these beds, are pebble bands with abundance of shells, and an alternation is remarked of one such band in the upper part of the Thanet sands which rest on the chalk. The Cyrenæ are often found with valves united. Remains of fishes (chiefly sharks and rays) occur.

What may be regarded as the uppermost member of the series under consideration is a capping of well-rolled flint pebbles, usually of small size, and in some places, as at Blackheath, of considerable thickness. These are sometimes loose as the pebbles on a sea-beach, and almost unmixed with sand, but elsewhere aggregated to a conglomerate. Possibly to this horizon should be referred the flint pebble bed or pudding-stone of Hertfordshire, which has what is called a siliceous cement, in which an evident granular texture remains to indicate its arenaceous origin.

On this point I may remark that in the Chiltern Hills, especially about Nuffield, large angular, irregular blocks of this kind of stone are found in the fields on the slope of the chalk, much as near

Marlborough and Ashdown, but not so prominent or so regular. They are often cavernous, like the 'Blowing-stone' near Uffington Camp. One of the largest is 8 feet in the longest diameter. At the Rectory, Rotherfield-Grays, several of these stones have been collected, one 6 feet long; and it is interesting to find them filled with flints, which are, except in their greater size, comparable with the pudding-stone of Hertfordshire. The basis is closely-cemented sandstone. Mr. Hopkins, M.A., of Magdalen College, made me aware of these localities. After examining these facts I was much impressed by the probability that all the deposits of this kind of stone in Wilts, Oxon, and Herts might be of the same or nearly the same geological date; very pebbly on the eastern side, partially so in the middle, rarely so, but occasionally shelly, in the western district.

Thus a tripartite pebbly series of sands, clays, and conglomerates represents the lowest eocene formation in the Thames valley; viz.—

Blackheath pebble-bed above.
Woolwich clays and sands }
Thanet sands below } with pebbles occasionally.

One of the best sections yet published of the Woolwich and Thanet beds is that of Loampit Hill, near Lewisham, in Kent[g].

Pebble-bed of Blackheath above.

Woolwich beds.	ft.
Fine sand, yellow, and iron-shot	10
Loam and plastic clay, with pyrites and leaves	10
Sands, yellow	3
Clay, lead-coloured, with leaves	2
Clay, brownish, with Cyrenæ	6
Clay, in three beds; the upper and lower contain Cyrenæ, the middle oysters	3
Loam and sand; upper part cream-coloured with nodules of friable marl, lower part sandy and iron-shot	4
Thanet beds.	
Ferruginous sand, with flint pebbles	12
Greensand, coarse and pebbly	5
Sand, ash-coloured, slightly micaceous	35
Greensand, with green-coated flints	1
Chalk with beds and nodules of black flint.	

Next above is a great deposit of blue sediments, the upper part sandy, the lower part strong clay, with septaria and bands of shells. This clay, cut through many years since in the 'Archway' at Highgate, furnished many shells which were figured in the early numbers of Sowerby's valuable Mineral Conchology. This 'London clay' is about 400 feet thick at Highgate, and nearly 500 feet in Sheppey Island, where it yields abundance of fruits and some animal remains indicative of warm climate[h].

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[g] Geol. Trans. vol. iv. p. 287.

It is covered at Hampstead considerably, and at Highgate partially, by a sandy deposit which is more extensively spread about Bagshot Heath, and therefore called by that local name. In all this tract it is but little fossiliferous; but on the south coast, as in Bracklesham Bay, where the full type seems to be exhibited, fossils are very numerous, and on the whole differ considerably from those of the London clay[i]. The highest land which it reaches in this area is the summit of Hampstead Heath, 430 feet above the sea.

This is the latest eocene deposit in the London basin. There are no meiocene or pleiocene beds, as those terms are commonly understood, nor any sure indication that such ever existed here.

In considering these remarkable strata, which were accumulated in a period so near, geologically speaking, to our own, we are presented with problems of great interest, which, if they can be solved, will have more than local application.

Whence came the materials, the clay, the sand, the pebbles; in what direction; by what forces urged? what were the tracts of sea and land; how deep the water, how high the land? what is the explanation of the appearance of fluviatile shells among oceanic exuviæ?

Of the materials a great part can be found in the country surrounding the drainage of the Thames on the north, west, and south; some of them can be had only within the drainage, as the flint pebbles which are certainly the gift of the neighbouring chalk, and specially the upper chalk. The clays and sands can be sufficiently matched by deposits of the earlier cretaceous, oolitic, and liassic ages, and conditions of land and sea may be imagined such as to allow of these materials arriving by ordinary means within the old sea-basin of the Thames. The most distinct hypothesis of such an origin of the clays and sands and ferruginous elements of the London eocenes is that investigated by Lyell, Prestwich, and others; which ascribes to the anticlinal elevation of he Wealden the origin of currents flowing to the northward and carrying the spoils gathered in their courses. We must not, for this transport of material, confine our view to the actual valleys which contain rivers now running; though it is probable that these hollows were really sketched out during the elevation of the Wealden; it is enough to observe that the height of the interior ridges of Kent and Sussex, from which the sands, clays, and iron oxides might come, was probably far greater at the time of their utmost elevation than now; while, in fact, the obvious and enormous waste from these ridges may well be appealed to in support of the hypothesis.

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[h] At High Beech, and Langdon in Essex, greater heights are assigned by the Ordnance Survey, but the measurements are not free from doubt.

[i] Prestwich, Journal of Geol. Soc. vol. x. p. 434.

If it be objected that separate fossils, and fragments of the peculiar sandstones, shell limestones, and argillaceous carbonates of iron which abound in the Weald should be often met with in the London strata, the answer may be, that if the transport were by ordinary rain and river action along gentle slopes in a mild climate, only fine-grained sediments, such as now descend the Thames and its branches, ought to be looked for.

To some extent these arguments apply also to the country north of the Thames drainage, and indeed to the whole range of the oolites in the upper valleys of the Thames. All this country has been wasted; there is no reason to deny that it was elevated so as to be capable of waste during the eocene periods; and the inclination of the strata is uniformly indicative of a general rise parallel to an axis from south-west to north-east.

Within the narrow sea, thus supplied with sediments, the distribution of these is found to be such as to determine in some degree the direction of currents, depth of water, and other conditions by which the successive deposits were affected. The lowest or Thanet beds of sand seem to be unknown in the western parts of the old bay, and to grow thicker from the middle eastward. The Woolwich beds of laminated clays, sands, and pebbles—products of shallow water, varying streams, and perhaps oscillations of level—have more uniform distribution in the area, though the mottled character of the deposit is most observed in the west, and the laminated shell beds are more frequent in the east. The pebble beds of Blackheath, the thickest known example, include generally small masses, but occasionally pieces occur six or eight inches in diameter, and suggest sea-shore action, somewhat like that on the Chesil beach, which, arriving at a maximum there, is yet part of a system represented by feebler shingle beds as far west as the extremity of Dorsetshire.

The London clay requires a totally different set of conditions to account for its comparative uniformity and freedom from sandy or gravelly admixture. Deep and tranquil water, instead of shallow and disturbed currents; fine sediment transported from afar, instead of pebbly aggregates left near the shores; quiet residence of mollusca in several zones, through long spaces of time—these are the main elements. There is, however, this to be added. The truly argillaceous character of the lower part changes to a fine-grained sandy clay in the upper part; a change quite natural if the sea depth were gradually reduced by mere accumulation through time; for thus the transporting power of watery movement would gradually increase, and larger and larger particles become capable of transport. Finally, this power of drifting sands and pebbles returned, and the London clay became covered by the Hampstead sands, but received, or at least has preserved, no later deposits of the eocene ages; while elsewhere, in another basin, that of Hampshire and the Isle of Wight, they were continued in a long succession; and these also came to an end, and were followed, after a long interval and in another branch of the cainozoic sea, by the fossiliferous zones of the crag.

The following Synopsis of the genera of fossils discovered in these eocene strata, within the drainage of the Thames, is offered as a convenient, though incomplete, list with which to terminate the long series of the forms of life, which, always varying with the lapse of time, and continually readjusted to new physical conditions, but always contained within the same organic formulæ, constitute one great body of evidence, one full and comprehensive scale by which to measure the succession and determine the periods of all the great revolutions

> 'Of Nature, constant in her ceaseless change.'

GENERA OF FOSSILS FOUND IN LOWER EOCENE STRATA WITHIN THE DRAINAGE OF THE THAMES.

Name of Genus.	Thanet and Woolwich Beds.	London Clay.	Bagshot Beds.
PLANTS.			
Fern	*		
Coniferous wood	*		
Leaves of sequoia?	*		
Fruit of a conifer	*		
Polycotyledoneæ.			
Callitrites[k]		*	
Frenellites		*	
Solenostrobus		*	
Monocotyledoneæ.			
Flabellaria	*	*	
Monocotyledonous stem	*		
Dicotyledoneæ.			
Amentaceæ		*	
Carpolithus		*	
Comptonia		*	
Cucumites		*	
Cupanoides		*	
Faboidea		*	
Hightea		*	
Lauraceæ		*	
Leguminosites		*	
Mimosites		*	
Nipadites		*	
Pterophylloides		*	
Tricarpellites		*	
Wetherellia		*	
Xulionosprionites		*	
Dicotyledonous leaves, several, some possibly of maples, others of poplars	*		
AMORPHOZOA.			
Spongia	*		
FORAMINIFERA.			
Alveolina		*	
Anomalina		*	
Biloculina		*	
Bulimina		*	
Dentalina		*	
Frondicularia		*	
Globigerina	*		
Globulina	*		
Marginulina		*	
Nodosaria	*		
Nummulites		*	
Operculina		*	
Polymorphina		*	
Quinqueloculina		*	
Robulina		*	
Rosalina		*	
Rotulina		*	
Textularia	*		
Triloculina		*	
Truncatulina	*		
ACTINOZOA.			
Dasmia		*	
Graphularia		*	
Leptocyathus		*	
Mopsia		*	
Stephanophyllia		*	
Turbinolia		*	
Websteria		*	
ECHINODERMATA.			
Crinoidea.			
Bourguetocrinus		*	
Cainocrinus		*	
Pentacrinus		*	
Asteroidea.			
Astropecten		*	
Goniaster		*	
Ophiura		*	
Echinoidea.			
Cidaris		*	
Cœlopleurus		*	
Hemiaster		*	
ANNELLIDA.			
Ditrupa		*	

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[k] In a general point of view the plants in the London clay indicate, in the opinion of Mr. Bowerbank, a warm climate; they are mostly seeds.

Name of Genus.	Thanet and Woolwich Beds.	London Clay.	Bagshot Beds.
Serpula	*	*	
Vermicularia		*	
Vermilia		*	
CRUSTACEA.			
Decapoda.			
Archæocarabus		*	
Cancer	*		
Cyclocorystes		*	
Dromilites		*	
Hoploparia		*	
Scyllaridia		*	
Thenops		*	
Trachysoma		*	
Xanthopsis		*	
Ostracoda.			
Bairdia		*	
Candona	*		
Cythere	*	*	
Cytherella		*	
Cirripedia.			
Pollicipes		*	
Scalpellum		*	
POLYZOA.			
Cellepora		*	
Crisia		*	
Eschara		*	
Flustra	*	*	
Lunulites	*		
BRACHIOPODA.			
Lingula		*	
Terebratulina		*	
MONOMYARIA.			
Anomia		*	
Avicula		*	
Ostrea	*	*	
Pecten		*	
Pinna		*	
DIMYARIA.			
Arca	*	*	
Astarte		*	
Cardita		*	
Cardium	*	*	
Corbula	*	*	
Cryptodon		*	
Cucullæa	*		
Cyprina	*	*	
Cyrena	*		

Name of Genus.	Thanet and Woolwich Beds.	London Clay.	Bagshot Beds.
Cytherea	*	*	
Dreissena	*		
Glycimeris	*		
Lithodomus	*		
Lucina		*	
Modiola	*	*	
Mya		*	
Neæra		*	
Nucula	*	*	
Panopæa		*	
Pectunculus	*	*	
Pholas	*		
Psammobia	*		
Sanguinolaria	*	*	
Solen		*	
Syndosmya		*	
Teredina	*	*	
Teredo	*	*	
Thracia	*		
Unio	*		
GASTEROPODA.			
Actæon		*	
Ampullaria	*		
Ancillaria		*	
Aporrhais		*	
Auricula	*		
Buccinum	*		
Bulimus		*	
Bulla		*	
Calyptræa	*		
Cancellaria		*	
Cassidaria		*	
Cerithium	*	*	
Chemnitzia		*	
Conus		*	
Cypræa		*	
Dentalium	*		
Eulima		*	
Fusus	*	*	
Hipponyx		*	
Hydrobia	*		
Melania	*	*	
Melanopsis	*		
Metula		*	
Mitra		*	
Murex	*	*	
Natica	*	*	
Nerita		*	
Neritina	*		
Odostomia		*	
Ovula		*	
Paludina	*		

Name of Genus.	Thanet and Woolwich Beds.	London Clay.	Bagshot Beds.
Patella	*		
Phasianella		*	
Phorus		*	
Planorbis	*		
Pleurotoma		*	
Pyramidella		*	
Pyrula		*	
Ringicola		*	
Rissoa ?		*	
Rostellaria		*	
Scalaria		*	
Sigaretus		*	
Skenea		*	
Solarium		*	
Triton		*	
Turritella		*	
Typhis		*	
Voluta		*	
Volvaria		*	
Cephalopoda.			
Belemnosis		*	
Beloptera		*	
Belosepia		*	
Nautilus		*	
Fishes.			
Acestrus		*	
Acipenser		*	
Aetobatis		*	
Ampheristus		*	
Auchenilabrus		*	
Bothrosteus		*	
Brachygnathus		*	
Brychætus		*	
Calopomus		*	
Carcharodon		*	
Cœlocephalus		*	
Cœloperca		*	
Cœlopoma		*	
Cœlorhynchus		*	
Cybium		*	
Edaphodon	*		
Elasmodus		*	
Goniognathus		*	
Gyrodus		*	
Halecopsis		*	
Hypsodon		*	
Labrophagus		*	
Lamna	*	*	
Laparus		*	
Lepidosteus	*		
Loxostomus		*	
Megalops		*	
Merlinus		*	
Myliobates	*	*	
Myripristis		*	
Notidanus		*	
Otodus		*	
Pachycephalus		*	
Percostoma		*	
Periodus		*	
Phalacrus		*	
Phasganus		*	
Pisodus		*	
Podocephalus		*	
Pomophractus		*	
Pristis		*	
Psaliodus		*	
Ptychocephalus		*	
Pycnodus		*	
Rhinocephalus		*	
Rhipidolepis		*	
Rhoncus		*	
Rhynchorhinus		*	
Sciænurus		*	
Scombrinus		*	
Sphyrænodus		*	
Spinax		*	
Teratichthys		*	
Tetrapterus		*	
Reptilia.			
Chelonia	*	*	
Crocodilus		*	
Emys		*	
Palæophis		*	
Platemys		*	
Trionyx		*	
Aves.			
Halcyornis		*	
Lithornis		*	
A small bird	*		
Mammalia.			
Coryphodon	*	*	
Hyracotherium		*	

CHAPTER XVIII.

PLEISTOCENE DEPOSITS.

The long series of palæozoic, mesozoic, and cainozoic strata being completed to the crag of our eastern coast, the distribution of land and sea where now are the British Isles was in some considerable degree sketched out. By early systems of movement the chains of the Highlands, and the south of Scotland; of Donegal, and the mountains of Mourne and Wicklow; the ridges of the north of England; the insulated groups of Charnwood and Malvern, and the elevated tracts of Wales, had been raised and settled into hills before the mesozoic age.

At a later time the mesozoic and great part of the cainozoic strata were pressed upward, and something like the main features of the oolitic and chalk ranges traced out as we now see them. Not exactly indeed; for the breadth of the oolites was then much greater to the west, so as to occupy, with crests equal to or surpassing the summit of Cleeve, what is now the Vale of Gloucester, and the chalk extended so much beyond the White Horse Hill and Marlborough Downs as to have furnished abundant heaps of unbroken and unchanged flints to the extremity of what is now the Vale of Evenlode. The regions mentioned were raised out of the sea, and placed above its level, and subjected to meteoric waste; and against some of the surfaces of this old land, where it passed under the sea, the crag and other strata were formed on lines of ancient coast, and at sea-levels not greatly differing from those now observed.

One might think that since the date of the deposition of crag, on the eastern coast of 'old England,'—parallel to what is now the East-Anglian shore,—the levels of land and sea had been little disturbed, beyond the 20 or 30 feet rise of the limited crag beds and more extended shell beaches into dry land. Yet it is generally admitted, and indeed seems incontestable, that after the date referred to the sea (or at least sea-water) once more covered the greater part of the British Islands, hiding lands which now are and previously had been eminent 1500 feet above the waves. The evidence for this marine overflow, which was probably no sudden catastrophe, but a gradual uprising of water, or subsiding of land, is sufficient in the district now under review to a height of 750 feet, and may be conjecturally admitted for more; but in Wales, the north of England, and Scotland it is satisfactory to even twice that height. The retreat of this water, or the subsidence of this land, was also probably gradual, not sudden, occupied a long time, and was attended by enormous local waste of surface. By both operations, long rising and falling movements, abundance of disintegrated earthy and stony masses acquired a new distribution; and on the glacial waters, for they seem to have been cold and to have nourished boreal mollusks, to areas once occupied by cognate races adapted to warmer climates, some larger blocks were carried far from their native sites in the Grampians and Lammermuirs, in Cumberland, Yorkshire, and Wales, to the plains of Cheshire and Staffordshire.

On this anciently upheaved and again deeply sunk sea bed, subsequently restored to its old level, worn and wasted, and with abundant marks of marine occupation, an entirely different set of deposits, in a considerable degree characterized by levels, composition, and organic contents, as river and flood sediments, has been collected in the course of the basin of the Thames. These are thought to be of various ages, but all may be understood as due to watery agency, principally fresh-water currents which flowed while the general surface of the country was not materially different in respect of elevation and contour from what it is at present. For these I employ the general title of *Valley deposits.*

But beside these gravels, sands, and clays, observed on the bed and on the lower slopes of the Thames basin, we find, sometimes in great quantity and often widely scattered over hills and dales, a variety of gravels and sands, or else of clay charged with angular, rolled, or rubbed stones, which have been brought from distant parts of England, or even from beyond the Isles of Britain. To these I assign the title of *Hill deposits*, not that they are exclusively found on elevated ground, but because this fact is characteristic of them, in contrast with the others. Scattered materials of these hill gravels are often found in low ground mixed with those in the true valley deposits, under circumstances which indicate the anterior date of the former. They have indeed often been swept down from their original sites on higher ground by rains and rivers, at some later time than the epoch of their arrival in the drainage of the Thames.

These hill gravels are composed of materials which it is impossible to suppose to have been drifted at any time or under any circumstances by water flowing as a river or inundation from atmospheric precipitations; the extent of ground occupied, and the nature of the pebbles and fragments, imply the agency of wide ocean streams, mostly directed from the northward to the southward. A marine origin is thus found for the hill gravels, but I am not aware of any modern reliquiæ of the sea being found in them within the drainage of the Thames, though ancient fossils are common enough among them in particular places. Floating ice has been suggested as the vehicle of the transport of these extra-Tamisian stones, and their geological date is expressed by the term 'glacial,' the valley gravels being universally admitted to be 'post-glacial.'

Flint implements—memorials of more than one early period of imperfect British civilization—have been found in the Thames Valley at several points in descending its course from Dorchester near Oxford to Reculver. Up to the present time they have not been discovered in the hill gravels, and only at small depths in or at the surface of the valley gravels.

Remains of mammalia occur in the valley gravel, silt, and peat; some of species long since extinct in these regions, as the mammoth and rhinoceros (both when alive covered with hair and wool), hippopotamus and bear; others formerly resident, as the beaver, roe-deer, red-deer, goat, and wolf; and others still feeding in our pastures and subject to domesticity, as the horse and the ox.

HILL OR HIGH LEVEL GRAVEL.

On a large portion of the Cotswolds, but not rising to their greater elevations, we find a scattered gravel deposit, of a kind entirely different from that which is so common in the greater part of the Thames Valley. It is not accompanied by boulder clay; contains no large erratic blocks; but a considerable variety of stones of greater size than such as are commonly found in gravel. Two sorts of stone are the most common: one is quartz, usually in small white pebbles, the other is hard reddish gritstone or quartzite, a metamorphic rock which corresponds with none *in situ* better than with that of Hartshill, near Nuneaton. This kind of stone may be collected from half the ploughed lands of Oxfordshire, on the southward slopes of the oolites, on the Chiltern hills, and in the Vale of the Thames about Oxford and Abingdon. I have never seen a fossil in it. It is probable that the new red conglomerates of Warwickshire and the midland counties may with justice be credited as the *immediate* source of the pebbles. Whence they came originally may be hard to determine; though *such* rocks as those of the Lickey Hill, and Hartshill—metamorphic sandstones of some palæozoic kind, possibly destroyed in early mesozoic ages—are clearly indicated[a].

In the vicinity of Oxford, this high level gravel may be observed, in the state of a coarse drift with masses several pounds in weight—of quartzite, felstone, and gritstone, but with little or no trace of the oolite so common in the lower gravels of the Thames.

On the clay hills at Bletchingdon and Kirtlington is a high level drift, remarkable for the abundance of small fragments of iron-oxide, such as occurs at the base of the oolite in several places further north, and an unusual red sand. On Leafield beacon the ancient tumulus is composed of white quartz pebbles, and various worn fragments of small size, derived from rocks far beyond the drainage of the Thames.

From observing facts of this kind Dr. Kidd, as early as 1815, while Professor of Chemistry, presented a clear division of the Oxford gravels, into two groups—the one a hill group, with stones brought from a distance; the other a valley group, containing portions of the neighbouring strata[b].

Dr. Buckland, in his celebrated work, entitled 'Reliquiæ Diluvianæ[c],' gives a map of the distribution of the drift in the vicinity of Oxford; by which it appears that he had observed the gravel containing pebbles of quartz rock (the red grit) in the Vale of the Warwickshire Avon generally; and in the Vales of the Evenlode, Cherwell, and Thames. This pebble drift is marked on the hills of Wychwood Forest, Wytham, and Bagley Wood, on the edges of the Cherwell Valley, on the lower surfaces about Abingdon, Dorchester, and Wallingford, and on parts of the chalk hills of Chiltern and the eastern extremity of Ilsley Downs. But Shotover and Brill, the whole range of the Cotswold, the country about Chipping-Norton, that west of Banbury and east of the Cherwell, are left free from the drift, which yet is marked in a considerable part of the upper drainage of the Nen.

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[a] See Brodie in Geol. Proc. 1867.

[b] Geological Essays, 1815.

[c] 1821, 4to. p. 279.

The map which represents these extremely interesting facts is described as 'shewing the manner in which the Lickey sandstone pebbles have been drifted from Warwickshire, through two low points—the escarpment of the oolite limestone, at Moreton-in-the-Marsh, and on the north of Banbury—and have been spread over the country along the valleys of the Evenlode, the Cherwell, and the Thames, and also on the north of Buckingham.' Masses of larger size than usual lie on the fields about Bladon and Handborough, crown the heights of Wytham, Cumnor, and Bagley Wood, and occur on the Chiltern hills above Henley.

The operation of a great flood, a deluge, coming from the north, north-west and north-east, with spoils of the highlands in these directions, before the excavation of the Oxfordshire valleys, is assumed by Dr. Buckland to explain the facts he has recorded. Cumberland and Charnwood Forest have yielded the quartz, felstones, gneiss, porphyry, and trap; the red sandstone of Bridgnorth and the midland districts has supplied the hard quartzite; Spilsby and Lincolnshire red and white chalk, and flints. The red quartzites in particular were carried down the whole Vale of Thames to Maidenhead and Kensington; but in some of these cases they occur in the valley, and must be noticed again with the 'low level' gravel.

The freedom from this gravel of all the higher oolitic country west of the Evenlode, which Dr. Buckland's map represents, is confirmed by the special researches on the subject of Mr. Hull[d], who was engaged in the geological survey of the district. Under the title of 'northern drift' he describes the pebbly deposit as being but sparingly distributed over the southern portion of the Gloucestershire plain; it occurs on the flanks of Bredon and Cleeve Hill; and is composed of materials brought from the north and the east. 'The greater portion of the Cotswold hills is entirely free from drift.' 'The whole table-land of the Cotswolds, from its western escarpment to the neighbourhood of Stow-on-the-Wold, is entirely free from the presence of erratic pebbles.' 'Their western limit may be roughly represented by a line drawn from the southern end of the Vale of Bourton to Cirencester, and on approaching this limit they become so sparingly scattered that their presence is only to be ascertained by carefully searching the ploughed fields.'

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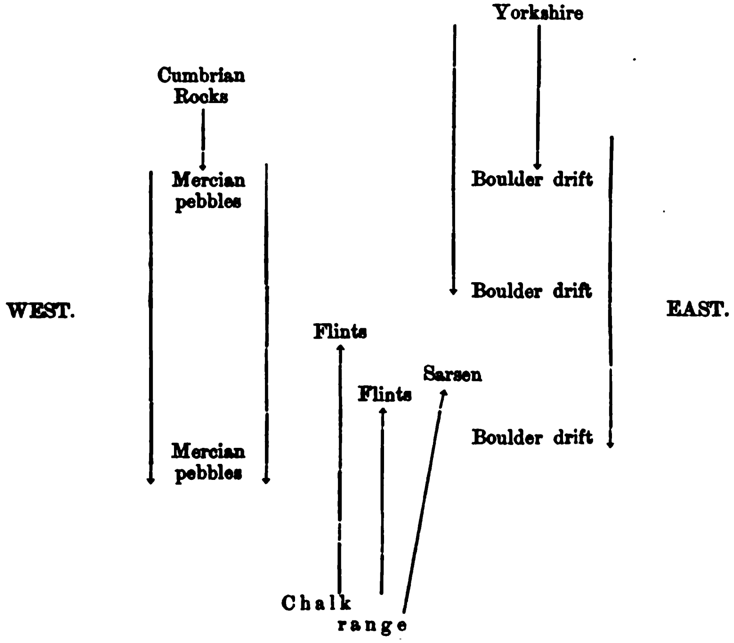
[d] Proceedings of the Geol. Soc., Nov. 1855, with a map.

Looking at the distribution of foreign drift in the country under review, we find evidence of abundant currents from the north which brought plenty of gravels on the western side, but no boulder clay; and plenty of boulder clay with some gravels on the eastern side; while in the middle space there are traces of currents from the south transporting flints and sarsen stones.



These latter, the sarsen stones, are instances which seem strongly to suggest, perhaps to require, the agency of ice; possibly, indeed probably, not icebergs broken off from glaciers which reached the sea, but shore ice, or frozen masses of earth, such as are believed to be recognised in particular accumulations of drift. If the Vale of the Ock were once a fresh-water lake, discharging through the gorge above Pangbourn, and the climate were 'glacial,' we should have the required conditions for the transport of the blocks near Swindon and at Long Wittenham. If it were a sea-loch communicating by a frith through the chalk to the broader sea below, the same results might follow.

But the great mass of drift pebbles in the Cotswold country and in the wide depressed and elevated regions round Oxford, does not on a first view suggest such an origin. Their actual distribution is due to watery movement on the surface where they rest. If icebergs brought these materials they seem to have left no definite trace of their passage. Still less do we perceive the marks of glacial friction on the surfaces where the pebbles rest. Yet the sudden changes of level and nature of materials of these deposits in particular limited and especially high situations—red northern drift, flint masses of every shape and various sizes, sometimes with unworn chalk, in separate patches or layers—give occasion for the opinion that something of ice action and currents, less continuous than ordinary streams, and less expanded than lake fluctuations or tidal swellings, must be called in to account for these facts. A climate cold enough in winter to suit the warm-coated elephant, or the hardy reindeer and bear, and cover the Cotswolds and Downs with a variable sheet of ice and snow far deeper than we now see, and subject to periodical melting, might account for the main phænomena in the lower grounds.

'In visiting the Shipston and Evenlode Valleys,' says Mr. Lucy[e], 'I was much impressed with the distinct evidence of the action of ice in all its varied forms of berg, land, and sheet; of the vast mantle of frozen snow and ice which, as it appeared to me, must once have lined the tops and sides of the hills, carrying down with it, when the summer thaws set in, the materials upon which it rested.' This is now a prevalent opinion in respect of many valleys and slopes occupied by abundant pebbly deposits, among which angular or slightly worn masses of stone, above a foot or 2 or even 4 feet in longest diameter, are found; solitary specimens from some distant point, but within the drainage. It combines well enough with the idea of expanded sheets of water in the upper drainage of the Thames, about Eynsham, Oxford, and Abingdon; where such masses are not very uncommon in broad tracts of gravel beds which indicate such surfaces.

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[e] Proceedings of the Cotteswold Club, 1869.

If we take the only other view, viz. that of strong currents of water competent to move such stones, some facts of importance appear hostile. First, such currents must have left more than solitary memorials of their velocity, which in the case of a four-foot block cannot be reckoned at less than 15 feet in a second, such as none but an Alpine river is known to attain; next, the blocks must have been rounded, for with that velocity they could only be moved step by step for short distances, by powerful inundations; thirdly, the directions in which they appear to have been moved are such as not to fit the idea of their being drifted on the bed of flowing streams of any kind. We may add their occurrence in and upon gravel which could not have remained to support them under the influence of such a current.

VALLEY OR LOW LEVEL GRAVEL.

Gravel is plentiful in the course of the Thames from the point where the several feeders enter the great vale which extends from Cricklade eastward; but it is not at all abundant along the course, and is quite scarce about the sources and in the upper branches of the streams which rise in the Cotswolds, and in the region between Evenlode and Cherwell. The upper parts of most of these valleys have the aspect of having been 'cleared out' by decurrent water.

The broad depressed tract about Down-Ampney and north of Cricklade is occupied by a nearly level deposit of gravel, composed mostly of small waterworn oolitic stones with some admixture of flints, to a depth of 6 or 8 feet. Near Minety there is a local drift of flints, now in use on the roads, but that is to be regarded as a part of the 'hill deposits' remodelled in lower ground. The

Ampney deposit, traversed in narrow channels by the existing streams, suggests the idea of deposition from land floods in a sheet of water subject to agitation. This gravel is about 270 feet above mean tide.

Where the Windrush directs its course toward the main stream a great body of gravel spreads on both sides, sloping gently southwards as the river descends. At Witney and Eynsham it is largely dug, from 260 to 200 feet above the sea, in thin undulated layers of oolitic stones, sand, and flints, with a considerable proportion of red quartzite. At Stanton-Harcourt it is partly consolidated to a conglomerate by infiltrated carbonate of lime and carbonate of iron, so as to be actually employed in building. At Yarnton the deposit is very extensive, and as much as 12 and 16 feet deep. It is formed of many irregular, mostly undulated layers of gravel and sand, with thin stripes of clay; the stones mostly oolitic, with admixture of flints, red grits, and white quartz; the height above the sea is about 210 feet. It yielded at and near the bottom, where large pebbles of northern drift formed an almost solid bed, a profusion of teeth and tusks of Elephas primigenius. In the upper part were old British pit-graves, with skeletons in the pits.

This gravel spreads northward up the sides of the curious hollow, which may have been an old channel of the Cherwell, to Kidlington Station, where it is in laminæ of stones, sand, and thin clay bands, yielding a few shells of land and fresh-water.

Oxford stands on a gravel bed, 8, 12, or even 16 feet thick, between the Thames and the Cherwell, and is supplied with water of good drinking quality by the rain which is filtered through the gravel and collected on the clay. On the left banks of the Cherwell a little, and in Cowley Field much gravel; on the right bank of the Thames, at Wytham, and North Hinksey, and indeed under a good part of the valley, gravel occurs. The height of this gravel-bed at Oxford above the mean level of the sea is about 210 feet.

Abundance of Gryphæa dilatata, Belemnites sulcatus, and Isastræa explanata, from Oxford clay and Coralline oolite, with fossiliferous fragments of Forest marble, occur in all situations. Flints almost unmixed with other materials occurred in an excavation at Summertown, but we sought there in vain for any ancient implement. Bones of the mammoth, rhinoceros, hippopotamus, ox, deer, and horse occur at Wytham, and in many places within a small space round Oxford.

Lower down, at Culham, is a broad plain of gravel on gault, greensand, and Kimmeridge clay. The composition of the gravel is much like that at Oxford, and it yielded similar bones of quadrupeds, Elephas antiquus being represented by a gigantic tooth. About Radley and Abingdon it is very extensive; and we follow it by Clifton-Hampden, Wittenham, Dorchester, Wallingford, Henley, Hurley, Marlow, and Maidenhead. But as we proceed the character of the gravel is found to change; in the upper part of the valley it is for the most part oolitic, in the middle part mixed oolites and flint, in the lower part flints prevail; but everywhere some pebbles appear of a hard reddish grit, like that of the Lickey Hill and that of Harthill near Nuneaton.

At almost every place of observation from Cricklade down to Wallingford we observe a curious defect of calcareous stones in the upper part of the cutting, in the soil and subsoil, whether the depth be one, two, or three feet. In that upper part flints, quartz, and red grits abound, and on many fields appear the only stones. In the gravel pits the lower stones of whatever sort are commonly coated by incrusting carbonate of lime; and in some cases, especially in the admirable river-bank sections at Long Wittenham, curved and implicated layers of white soft carbonate of lime lie in some abundance for short spaces. Hence we infer that long atmospheric and vegetative agency, the rains of some hundreds or thousands of years, aided often by processes of cultivation, have dissolved the carbonate of lime in the parts near the surface, and carried it down to make the soft white sheets or the harder semicrystalline incrustations referred to.

The principal deposits of gravel are above the level of the river Thames, 10, 20, 30 feet: except in the Oxford ridge, they are on a long and broad surface sloping toward the great valley, and appearing to have been brought down by active streams, which now transport no material of the sort, except in gushes, and then merely displace small quantities.

The composition of the deposit varies much, as already observed; the arrangement of the materials less so, being always such as to indicate partial 'sorting' of the small pebbles and sand, and distribution in layers with occasional false-bedding. In the numerous excavations about Oxford, the sections shew thin interrupted bands of sand, and sandy clay, with small land and fresh-water shells. The pebbles of hard red sandstone are always much rounded, seldom above 4 inches long: those of coral and oolitic limestone are worn away at the edges and surfaces, sometimes as much as 12 inches long; the flints are worn or angular, not exceeding 4 inches in length, and not seldom have many surfaces of fracture, in some degree resembling the more obscure orders of 'chipped flints.' These many-surfaced flints are usually of a browner or yellower tint than the others, and must have been subject to some different natural conditions. Small quartz pebbles, white or yellow, one containing tourmaline, occur much rolled.

The low gravel of the Oxford valley and all its branches, as far as we have ascertained, is wholly of fluviatile or lacustrine arrangement. The action of limited and eddying waters, subject to frequent interruption and change of transporting force, is plainly evidenced by pebble bands, sand patches, and clay bands. The local variations are frequent and sudden, but there is one general character of the deposit: the greater portion of the materials is to be regarded as having been drifted down the valley; such materials are to be looked for *in situ* in the country farther northward, by the sides or toward the sources of the actual streams, or else on the hills where quartz, red grit, and other extra-Tamisian stones were left by oceanic waters of early date.

This indication of the fluviatile accumulation of the gravel is confirmed on a close search into the finer loam and clay bands, sometimes a little peaty, which interlaminate the sands and gravels. In these layers shells of land and fresh-water types occur, in situations 10, 20, and 30 feet above the present floods, and at points removed 100 or 1000 yards beyond their range. Mr. Prestwich and myself made a search of this kind in the large gravel pit close to the Kidlington Station on the Great Western Railway, four miles north of Oxford, and at some other points. We found shells lying in an argillaceous band 3 feet under gravel in the Kidlington pit; and somewhat to our surprise, from damp clay among gravel, in a small excavation by the road-side, on our way homeward from the village of Kidlington, we extracted small specimens of Ancylus fluviatilis.

Several years previously Mr. H. E. Strickland collected shells from loamy bands which divide the gravel at Summertown, north of Oxford, not far from Port-Meadow, and 20 feet above the present floods. These shells are in the Oxford Museum, and appear to be of the following species:—

Pisidium amnicum.
Limnæa peregra.
Pupa muscorum.
Valvata cristata.
Bithynia ventricosa.

Lately, on renewing a search in the pit at Kidlington, I regretted to find that the low cliffs of gravel were mostly destroyed. In a band of loamy consistence, two feet deep, under gravel, were found the following shells:—

Planorbis marginatus.
Achatina acicula; some specimens clear and pellucid (recent), others white and chalky.
Helix rufescens.

In the sandy drifts mixed with this gravel at Yarnton, to the depth of 10 feet, we find land shells; viz. Pupa muscorum, in plenty; Helix hispida, a few; and one fresh-water shell, viz. Limnæa peregra, a few small specimens.

The clay-pits at Summertown, excavated through gravel some twenty feet above the floods, have yielded at a depth of ten feet—

Ancylus lacustris.
Limnæa peregra.
Helix radiata.
Valvata piscinalis.

The gravel deposits near Wittenham have fortunately been watched with interest by a good observer, the Rev. J. C. Clutterbuck, M.A., Vicar of the parish. In this gravel deposit, containing oolitic fragments, chalk flints, and red quartzite, are some bands of finer matter, a kind of sandy loam mixed with small vegetable fragments—a laminated, somewhat peaty deposit from stagnating water. In a thin deposit of this kind, at a depth of five feet under gravel, were found the following shells:—

Bithynia tentaculata, in plenty.
Pupa muscorum, in plenty.
Helix rufescens.
Valvata cristata (?).
Pisidium amnicum.

By observations of this kind the fresh-water origin of the gravel-beds is sufficiently plain, as far down as the great vale expanding below Abingdon.

The gravel-beds were formed in broad waters, which were divided into irregular expansions above Yarnton and Sandford, and above the long-winding valley which extends from Moulsford to Reading. Whether we regard these 'broads' as formed at two or more levels by natural impediments at Yarnton, Sandford, and Moulsford, or treat the whole as one ramified loch gradually emptied by the deepening of one gorge below Wallingford, we shall arrive at the same general idea of the arrangement of the gravel being due to the fluctuations of these waters. As they retired southward they left the gravel at lower and lower levels, with no distinct steps, but rather on continuous gentle slopes, broken here and there by irregularly undulated mounds.

The gravelly strata in the uppermost of these sheets of water lie chiefly on the north side from Ampney to Yarnton, and on the east side from Kidlington to Cowley. One may believe this to be in some degree the effect of the prevailing winds from the south-west, for these depend on conditions far older than the pleistocene ages, and their effects have been traced in mesozoic and even in palæozoic periods by philosophical observers like De la Beche and Sorby. Thus, perhaps helped by floating ice, we may understand the drift of flints which runs so far in these gravels and beyond them to the north of the Berkshire downs, and lies in deep accumulations about Stadhampton, north of the Chilterns.

In a general manner, we may assign to the true sea-drift from the north—the earliest in our history—in the course of the Thames drainage above Pangbourn, a height not exceeding 750 feet; to the flint-drift from the south, which may have been marine, and must have been, at least in part, of later date, something like two-thirds of that elevation; and to the gravel-beds, in which both flints and quartzites have been mixed with oolitic fragments, something above one-third.

In descending the Valley of the Thames below Reading we remark the scattering of gravel (with northern pebbles) on the hill summits and slopes, and the gathering of thicker beds in the lower ground. At Hurley-Bottom, below Henley, a very productive spot for mammalia (mammoth, rhinoceros, bear, horse, ox, deer), the gravel, abounding in flints as might be expected, was accumulated in irregular hollows of the chalk; at Maidenhead spread out in broad plains and rudely parallel layers, on the wasted and pitted surface of the chalk.

At Brentford the pleistocene deposits above the London clay have been successfully examined, long since by Trimmer[e], and twenty years since by Morris[f]. The memoir of the latter geologist, which fills up the lacuna between the Oxford sections and those below the metropolis, contains the following section:—

	ft.	in.
8. Vegetable mould	1	0
7. Brickearth, a fine brownish loam	4	0
6. Fine sand, mostly stratified and obliquely laminated, with wavy and irregular veins of small gravel	6	0
5. Sand with light-coloured clay and irregular gravel, containing bones (average)	0	7
4. Ferruginous gravel and sand, with patches of clay	1	0
3. Clayey sand and sandy gravel, with occasional large flintstones, partly ferruginous at the upper part, containing shells and bones	1 0 to 2	0
2. Ferruginous sand and gravel	0	6
1. Light clayey sand and ferruginous gravel, with boulders of quartz granite rock with ammonites, &c., also bones of ox, deer, &c.	6 to 7	0

London clay below.

This section represents the main features of the Yarnton pits, with the layer of northern and other boulders at the base, above which were found most of the mammoth remains. The shells found by Professor Morris and Mr. Layton in the bed here marked 3, were the following:—

Bithynia impura.
Succinea amphibia.
Valvata piscinalis.
Limnæa auricularis.
Limnæa stagnalis.
Pisidium amnicum.
Cyclas cornea.
Anodon anatinus.

These land and fluviatile shells support the conclusion that the deposit is due to fluviatile action 'far more deep and extensive than that of the present river.'

The mammalian remains consist of—

Bos longifrons.
Cervus elaphus.
Cervus tarandus.
Felis spelæa.
Elephas primigenius.
Rhinoceros tichorhinus.
Hippopotamus major.
Bison priscus.

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[e] Phil. Trans. 1813.

[f] Geol. Soc. Journ. 1850.

They were little or not at all worn by attrition, and long tusks of elephants were found entire.

Plentiful and frequent as are the pleistocene mammalia in the upper and middle parts of the Thames Valley deposits, they appear even more abundant as we pass eastward beyond the metropolis. On the north side of the river, at Ilford and Gray's-Thurrock, and on the south side at Crayford and Erith, not to mention other localities, a larger series of these fossils has been obtained than from the upper parts of the drainage. The section at Uphall Pit, Ilford, as it appeared lately in the large brickfield there, presented the following circumstances[g], on the eastern side, where many bones have been found :—

Section of Uphall Pit—east side.

	ft.	in.
Soil, dark sandy with scattered pebbles	3	0
'Uncallow'—consisting of gravel, bands of sand, brickearth, and loam, generally ferruginous, much confused in arrangement. Some pebbles have the long axis vertical[h]	7	0
Sandy loam	2	3
Sand, yellow and ferruginous, curved and irregular, with scattered gravel	4	0
Gravel and sand, irregular bed	0	4
Sand and gravel scattered as above, yellow and ferruginous	3	0
(Mammoth, rhinoceros, and bison found here.)		
Shell-bed of Anodon, Unio, and Cyrena (Corbicula) fluminalis	0	6
(Undisturbed deposit of shells living on the spot)		
Clay, laminated, below the shells	1	0
Pebble-bed in sand of a greenish and ferruginous aspect (not penetrated).		

The series of these irregular layers varies from point to point, and suggests the intermitting action of violent land floods, snow melting, and drifting of shore ice, much as the gravel-beds farther up the valley. Loam and brickearth, the terms used in the district, are not exactly expressive of the deposits; both are very sandy, the former most so, and all the sorts of sands, gravels, loams, and brickearth are much confused together, except toward the bottom of the pit.

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[g] The manager was so kind as to have the lower portions exposed by digging in my presence, June 1871.

[h] Dawkins observed in this bed a large mass of 'Gray-weather' stone. Proc. Geol. Soc. 1867.

Section of Uphall Pit—south side.

	ft.	in.
Soil, dark, sandy, with scattered pebbles	3	0
Thick bed of 'Uncallow,' consisting of gravel, brickearth, loam, and sand, in horizontal, curved, and aggregated masses; the gravel containing much flint and some quartz; some of the pebbles placed with the long axis vertical; general colours pale, ochraceous, and ferruginous	10	0
Brickearth, pale, bluish, and ferruginous	2	6
Sands, mostly ferruginous, tinted in parallel but disturbed layers (5 or 6 feet seen)	6	0

(Green sands said to occur below.)

The shelly clays, sands, and gravel-beds thus associated are found at many places on both sides of the valley below London, and present endless small variations, even in single brickfields; they evidently belong all to one geological period, and one set of variable physical conditions. Their geological date, judged by these conditions, would seem to be post-glacial, if the upper beds, deposited in disturbance, may be regarded as re-composed from the glacial deposits on the neighbouring hills. This explanation is suggested by the case at Grays, where over the chalk and its covering sands, which form elevated ground, appears very much such a mixture as the 'Uncallow' in the lower grounds of Ilford and Grays; and it seems to 'tail down' from the high ground to the low, where it is collected in such a way as it may be supposed hasty floods and ice disturbance often repeated might occasion. It is not likely to have been produced by ordinary free fluctuation of water, because of the confusion of bedding, want of horizontal sorting, mixture of specific gravities, inequality of masses, and sudden local changes.

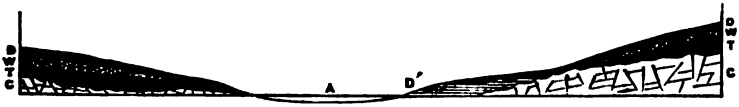

Diagram CCII. Section across the Vale of Thames from Erith to Grays-Thurrock. C. Chalk. T. Thanet sand. W. Woolwich beds. D. Hill-drift. D′. Cyrena or Valley-drift.

But for these circumstances one might fancy the deposits of shells in the places of their growth more ancient than the earliest distribution of the gravels of the vicinity; that they were pre-glacial, and only inferior in age to the Forest-bed of the Norfolk coast[1].

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[1] In considering this question Mr. Tylor's careful Sections should be consulted. Geol. Proc. vol. xxv. 1869.

If next we consider the shells, many of which belonged to residents on the spot,—a large list, including terrestrial, marsh, and aquatic races,—we find almost all to be living English species of Cyclas, Pisidium, Unio, Anodonta, Paludina, Bithynia, Valvata, Planorbis, Limnæa, Ancylus, Limax, Succinea, Zonites, Helix, Pupa, Vertigo, Clausilia, Zua, and Carychium, but some belong to a different category, as—

Cyrena (Corbicula) fluminalis.
Pisidium amnicum var. sulcatum.
Unio littoralis.
Hydrobia marginata.
Paludina contecta.
Valvata var. antiqua.

Of the whole number (about fifty-seven species) twenty-four or twenty-five[k] occur also in the Forest-bed of Norfolk, Paludina contecta being one of them. These circumstances seem to agree with the putting the lower brickearths within the glacial æra. Lastly, the mammalian remains of these interesting deposits have been carefully tabulated by Mr. Dawkins[l]:—

MAMMALIA OF THE LOWER BRICKEARTHS OF THE THAMES VALLEY.

Bear—Ursus arctos	Ilford.	Grays.	Crayford.	..
„ Ursus ferox	Ilford.	Grays.	Crayford.	..
Wolf	Ilford.	Grays.	Crayford.	Erith.
Fox—Canis vulpes	..	Grays.	..	..
Hyæna spelæa	..	Grays.	Crayford.	..
Felis spelæa	Ilford.	Grays.	Crayford.	Erith.
„ catus	..	Grays.	..	..
Lutra vulgaris	..	Grays.	..	..
Bison priscus	Ilford.	Grays.	Crayford.	..
Bos primigenius	Ilford.	Grays.	Crayford.	Erith.
Megaceros Hibernicus	Ilford.	Grays.	Crayford.	..
Cervus elaphus	Ilford.	Grays.	Crayford.	..
„ capreolus	(?)	(?)	..	..
Ovibos moschatus	..	..	Crayford.	..
Elephas antiquus	Ilford.	Grays.	Crayford.	Erith.
„ primigenius	Ilford.	..	Crayford.	Erith.
„ priscus[m]	..	Grays.	..	..
Equus fossilis	Ilford.	Grays.	Crayford.	Erith.

[k] Mr. Alfred Bell has communicated to me a complete list of the shells, with interesting remarks, which I hope may be speedily published.

[l] Geol. Proc. 1867. This list has been revised by Mr. Dawkins.

[m] Admitted as a variety of E. primigenius by Falconer.

Rhinoceros tichorhinus . .	Ilford.	..	Crayford.	..
„ leptorhinus . .	Ilford.	Grays.	Crayford.	..
„ megarhinus . .	Ilford.	Grays.	Crayford.	..
Sus scrofa	..	Grays.	..	..
Hippopotamus major . .	..	Grays.	..	..
Castor fiber	Ilford.	Grays.	..	..
Arvicola amphibia . . .	Ilford.	Grays.	Crayford.	..

So many of the animals in this list are found in deposits of all pleistocene ages, except those very near to our own, that it is only by attaching great weight to occurrences of some and persistent absence of others, that any clear evidence of geological date can be obtained. In this way two species catch attention by their presence, viz. Elephas priscus and Rhinoceros megarhinus, for these occur in the Forest-bed, and have not been seen in post-glacial gravels certainly proved to be such. The absence of Elephas meridionalis, Rhinoceros Etruscus, and Cervus arduus, which occur in the Forest-bed, weighs in the contrary direction. But again, the higher antiquity is supported by the absence of the reindeer. On the whole then, according to all the evidence, we may regard these deposits as rare examples of a peculiar kind, whose place in time is somewhere between that of the late pre-glacial and early post-glacial ages, when the levels of the country were different from what they are at present.

In the gravel of the Thames valley, and in peaty and lacustrine deposits associated with it, but of less antiquity as a general rule, at various points along the course of the river and its branches, but most plentifully below the junction of the Evenlode, lie scattered bones of many animals, some belonging to species now living in domesticity—as the horse and the ox; others formerly wild in this region—as the red-deer and the wolf; others long since erased from the catalogue of northern life—as the rhinoceros and the mammoth. The following is a general catalogue for the upper drainage of the Thames; and specimens of some part or other of each of these animals are in the Oxford Museum :—

	Gravel.	Drift Clay, Peat, &c.
Man	Flint implements in the upper parts. Dorchester, Wittenham[a].	Cranium[o], near Swindon.

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[a] Collections of the Rev. J. C. Clutterbuck and the Author.

[o] Collected by Mr. Brown of Cirencester.

	Gravel.	Drift Clay, Peat, &c.
Bear (Ursus arctos)	Hurley Bottom [p].	
Dog or wolf, large specimen	Gravel near Oxford [q].	Cherwell valley, above Magdalen College [r].
Cervus capreolus	Marcham [s]. (Full size.)	Stanlake [t]. (Young.)
„ elaphus	Wittenham, Oxford, &c.	Near Oxford, Swindon, &c.
„ tarandus	Wittenham. (Young.)	
Strongyloceros spelæus [u]	Abingdon.	
Capra hircus		Locality ?
Bos primigenius	Oxford, Abingdon, Thame, &c.	Stowe Wood.
„ longifrons		Near Swindon, &c.
„ taurus		Near Oxford.
Bison priscus	Hurley Bottom.	
Hippopotamus major	Wytham.	
Sus scrofa	Wytham.	Near Swindon, Oxford.
Equus fossilis	Oxford, Wytham, Culham, &c.	Above Magdalen College, &c.
Rhinoceros tichorhinus	Wytham, Kidlington, Oxford.	Near Wantage.
Elephas antiquus	Culham, Thame, Hurley, Wytham.	Above Magdalen Bridge.
„ primigenius	Ascott, Bourton, Yarnton, Oxford, Culham, Radley, Moulsford, Thame, Hurley, Cricklade, &c.	Lawford, near Rugby.
Castor fiber		Newbury.

This short Catalogue being compared with that furnished by Mr. Dawkins for the Lower Brickearths of the Thames valley, shews deficiencies of

Felis spelæa—F. catus.
Hyæna spelæa.
Ursus ferox.
Canis vulpes.
Lutra vulgaris.
Ovibos moschatus.
Megaceros hibernicus.
Elephas priscus.
Rhinoceros leptorhinus—
R. megarhinus.
Arvicola amphibia.

That the mammoth and rhinoceros lived on the borders of the Thames valley will readily be admitted; but that they were ever seen there by human eyes is quite another matter. No reliquiæ of humanity have been discovered to accompany them in the deep parts of the gravel where they mostly appear, as at Yarnton, nor even in the superficial parts where bones of horses are mixed with them, as in the Cherwell valley above Magdalen College. Their date is prehistorical in Europe, and, in the limited tract of the Thames valley, may be set down as belonging to and following the so-called glacial æra. They existed during the whole or part of the long period of time which witnessed the accumulation of the valley gravels, before the river flowed in its actual channel, before the dry gravel plains at the embouchure of the Windrush tempted the poor 'aborigines' to dig their hollow dwellings, and before the reindeer retreated from Gaul and Albion to the still snowy regions of the north.

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[p] Dr. Buckland's collection. [q] Presented by Professor J. E. T. Rogers, M.A.

[r] Found in dredging to deepen the channel. [s] Dr. Buckland's collection.

[t] 'From a depth of 5 feet in a bed of peat, lying beneath a stratum of gravel and one of clay, the top soil being peat; Stanlake, Oxon, 1851.' Presented by the Executors of Mr. Stone.

[u] Possibly a gigantic variety of Cervus elaphus.

But something more is to be said. Though the search for chipped and polished flints in the Oxford gravels has up to this date been quite unproductive, it is not so at Wittenham. There at different times, in the gravel banks above the river-floods, or else in the gravelly river-bed, a few remarkable specimens have been found.

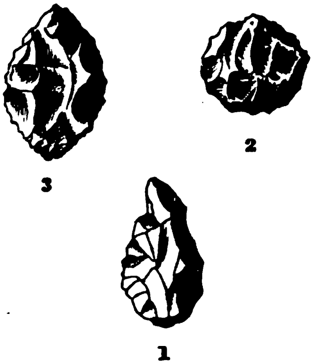

Diagram CCIII. Implements from the drift. Scale one-fifth of the objects.

1. Flint—Rude form of the type of St. Acheul chipped on the face shewn, the other being obtained by a single stroke. Others of this form and of larger size occurred at Long Wittenham, in gravel; and one in a peat bed at Winslow, resting on boulder clay.
2. Flint—Nearly circular, thick, chipped all round and on both faces. Long Wittenham.
3. Flint—Lanceolate in form, thin, chipped all round and over both surfaces. Hounslow Heath.

Those dredged from the river-bed have probably been removed a short distance by watery action from the gravel-banks above.

One retains the crust of carbonate of lime usual on many of the fragments and pebbles found in that gravel. Taken in the order of their relative rudeness and probable date, the first (Fig. 1) is of the early type of Amiens and Hoxne—a wedge of flint chipped to a triangular shape in front by the aid of many blows. Its surface is 'patinated,' as the expression now is, and it has undergone wearing. It was dredged with gravel at Wittenham. Fig. 2 is a round thick-edged 'scraper' from Wittenham, and Fig. 3 a peculiar specimen from Hounslow.

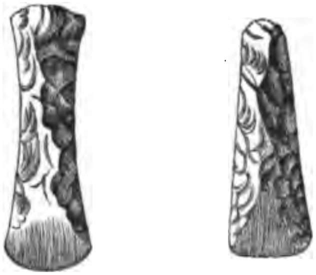

Diagram CCIV. Implements from the drift. Scale one-fifth of the objects.

4. Flint—Tapering, chipped on both edges and over both faces, and polished by friction to one curved cutting edge, not injured by use. Long Wittenham.
5. Flint—Expanded at both ends, chipped on both edges and over both faces, polished at the broader end to a curved cutting edge, a little broken by use. Long Wittenham.

The next to be noticed (Fig. 4), of much advanced workmanship, also obtained from the river-bed, is thickly encrusted at many points by the calcareous deposit usual in the gravel, and sometimes also observed as the effect of the river water. It is a chisel or hatchet blade, made from a dark flint flake, almost six inches long, expanding from less than an inch at one end to almost two inches at the other. The sides have been straightened and brought to an undulated edge by about one hundred effective blows or pressures, of which the traces remain. The broad end is ground smooth on both sides to a curved sharp edge, which apparently has been uninjured. It resembles specimens from the north of Ireland. Weight, 6·25 oz.

Another fine example, similar, but larger and expanded at both ends, is from the same locality (Fig. 5). Weight, 7½ oz.

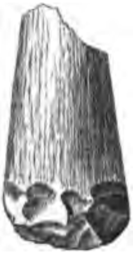

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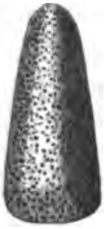
Diagram CCV. Ancient implement. Scale one-fifth of the object.

6. Flint—Of a yellow tint externally, smoothly ground with sand and water, over all the surface, the edges truncated, the broad end broken by use. This was probably 9 inches long when perfect. Long Wittenham.

The last (Fig. 6) is a grey flint instrument of larger size, which is 2½ inches broad at the chisel end, and tapers from this through a length of 5½ inches. Probably in its entire state the length might have been 8 or 9 inches; the narrower half was broken off at the time of finding, and has not been recovered. The broader end, much chipped, was found in this condition, the broken surfaces ochre-stained like all the rest of the surface. The chippings here alluded to appear to be the effect of using the instrument like a hatchet or chisel. They break through the general surface, which now is for the most part, and was when finished by the warrior or workman, altogether smoothly ground, surfaces and edges, by longitudinal sweeping strokes. Sand and water were the grinding materials, as may be seen by examining the striations and minute pittings which cover the surface. This curious specimen was obtained from the gravel bed of Wittenham removed from and above the level of floods. Weight, 11·5 oz.

All these specimens were made known to me by Mr. Clutterbuck.

In one respect, a more interesting specimen still (Fig. 7) came lately to my hands as the fruit of a dredging for gravel (Feb. 1871). This weapon is of ordinary greenstone, such as may be had in Devonshire and Cornwall. Some of the component parts have in places become decomposed; but the specimen is entire, and retains over nearly all the surface the remains of originally complete smoothing, though not the polish. Length, 5 inches;

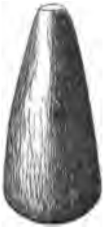


7

Diagram CCVI. Ancient implement. Scale one-fifth of the object.

7. Greenstone—Thick, partly decayed by removal of some of the felspathic portions, and partly incrusted by carbonate of lime, as many objects are found to be in the Oxford gravels. Smoothed over all the surface, broader end polished to a curved cutting edge. 'Found in the river Thames at Vincent, near Wittenham, while dredging gravel, Feb. 21, 1871.' (My collection.)

extreme breadth at the cutting-edge in front, 2·1; greatest thickness, 1·5. The front edge is arched, sharp, uninjured; the sides curved toward the smaller end. Calcareous incrustations appear in several parts where decomposition has happened. Weight, 13·5 oz.



8

Diagram CCVII. Ancient implement. Scale one-fifth of the object.

8. Soft fine-grained greenstone—Of a pale tint, smoothed over all, with edges truncated (as in Fig. 6), the broader end curved, sharp-edged; uninjured by use. 'Found in the clay of the brick-yard, Shotover Hill, May 21, 1861.' (My collection.)

A specimen (Fig. 8) almost the counterpart in form of this fine greenstone axe was found near the surface in the clay pits of

Shotover, and delivered to me on May 21, 1861. It is made of a yellowish grey sectile, uniformly fine-grained stone, on which steel is rapidly smoothed as on a soft hone, such as might perhaps be obtained in a metamorphic or slaty district, like North Devon. The curved front edge is quite sharp and uninjured. Weight, 12 oz. Length, 5·6 inches; extreme breadth, 2·2; greatest thickness, 1·25.

Of later date a bronze 'celt,' very perfectly cast, with curved sharp edge and lateral annulus; spear-heads of iron, and coins and pottery of imperial Rome, bring down the long history of man in the Thames valley to our Anglian period, at and near the fortress of some forgotten race which crowns one of the picturesque outliers of chalk at Wittenham, named Sinodun.

That 'monticule' stood up in the broad waters which once filled the Vale of Ock and Thame, between the chalk downs and the oolitic hills; round the hill and under the waters were spread sheets of gravel, the gift of many ages of watery movement. The waters pass away, the gravel beds are dry; wild foresters and fishers, hunters and boatmen, dig their homes and find warmth in their native earth. Long hours of leisure in 'winter and rough weather' are given to the chipping and grinding of flints—some for ruder work, others for rarer, emblematic, ornamental, or sacred purposes. Then as time passes, but is not counted, celts replace the stones; war changes the bivouac to a camp; the Roman road obliterates the British way; Christianity settles in Wessex, and establishes its first episcopal seat at Dorchester under the shadow of Wittenham camp, amidst the ruins of ancient days, forgotten creeds, and unrecorded associations of many-languaged men.

In the peaty deposits, which are of considerable extent and thickness in the lower part of the Vale of Kennet, flint implements have been found with bones of various animals. Two of these implements, similar in general form, 8·1 and 8·2 inches long, 2·5 and 2·9 wide at the edge which seems intended for use, and 1·25 and 1·5 at the other, are of unusual interest. One is carefully chipped to a tapering figure; the other has been so chipped, and afterwards smoothly rubbed down over the whole surface to a curved cutting edge, which is uninjured. Thus they correspond to two already described from Dorchester, and help us to the approximate geological date of the earliest traces of man in our valleys, viz. after the whole or greater part of the gravel was deposited[x].

From the gravelly drift on the Reculver cliffs, not far from the Roman station, flint implements of corresponding general aspect have occasionally fallen on the beach[y].

Sharp-edged, and often pointed, flakes—pieces struck off by single blows from a mass of flint—are met with at the old prehistoric settlement of Brighthampton, near the monoliths of Stanton-Harcourt (p. 57); and again in profusion at Dorchester, near the ancient mound of Sinodun, the Roman camp of Durocina, and the Saxon graves of Wittenham.

By observations of this kind we learn that Saxon, Roman, and British races have in succession congregated on particular spots, in situations which had been previously occupied by earlier people of ruder habits, of simpler diet and coarser clothing, who perhaps had lost all memory of their connection with the outer world beyond the sea, and believed themselves to be the 'aboriginal' people, the only children of the first of men[z].

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[x] I am indebted to Dr. Palmer for the knowledge of these fine specimens and photographs from which the measures were taken.

[y] Dr. Rolleston has shewn me good examples.

[z] 'Britanniæ pars interior ab iis incolitur, quos natos in insula ipsa memoria proditum dicunt. . . . Interiores plerique frumenta non serunt, sed lacte et carne vivunt pellibusque sunt vestiti.'—CÆSAR, De B. G. v. 12-14.

CHAPTER XIX.

GEOLOGICAL REVOLUTIONS. WASTE OF THE EARTH'S SURFACE BY THE SEA AND ATMOSPHERE.

THE land and sea of Britain had acquired the nearly settled condition in regard to limits, levels, and climate, which we now behold, when first the rude inhabitants gave signs of humanity by inventions to meet the wants of barbarian life. How this condition had been attained; what a long series of physical changes had visited every point of the area; how repeated were the movements; how frequent the alternations of wasting lands and refilled sea-beds, is the subject of geological history. Never-ceasing action from within to raise or depress, ever-recurring vicissitude from without to waste what had been raised and to heap fresh matter in the sea-bed which had sunk, these unquiet agencies are still at work to break the repose of nature; but their power is weakened, and a thousand years of ordinary processes pass and seem to leave no monuments of change worthy of being counted among the 'revolutions of the globe.' Yet in a period comparatively modern, according to geological chronology, a change has taken place in the northern regions of the globe, on a scale hardly to be surpassed by any earlier 'cataclysm.' For it is no longer as a plausible hypothesis, but as a theory founded on a connected history of real occurrences, that we admit of the doctrine of a general cooling of our now temperate regions to the condition of Greenland, accompanied by great rising and falling of continents and sea-beds, since the now living races of plants and animals came into existence. The land is believed to have been covered with snow and glaciers; next, to have been depressed 1000 or 1500 feet below its present standard, when shells of the old sea-shore were left on the sides of the mountains of North Wales and the North of England; and lastly, to have recovered its former elevation and climate.

In considering the causes of these movements it has usually been taken for granted that the sea-level has been constant, or subject only to such limited variations as may be consistent with (*a*) change of position of the axis of rotation of the globe; or (*b*) change of position of the centre of gravity along this axis. A change of position of the axis of the earth, though not much regarded by geologists or astronomers, is theoretically possible, because every displacement of matter within the earth or at the surface may alter the balance of rotating forces: but the effect can only be of a very small order, and not in any degree effective toward such great changes of oceanic level as the case in hand requires.

Displacement of the centre of gravity from causes acting below the surface is also to be included among possible events, but of too minute a range to be influential on the mean level of the sea.

Another cause of such displacement is found by Adhemar in the periodical phænomenon of 'precession of the equinoxes,' whereby first one polar region of the earth and then the other is presented favourably to the sun for 10,500 years; and again in another period of equal length the conditions are reversed. Thus periods of greater and less cold visit the polar regions alternately, and it is supposed that by this means snows gather round one pole and diminish round the other in sufficient quantity to change the place of the centre of gravity of the globe. The reasoning is correct, but the result cannot be sufficient for the present purpose.

By the researches of Herschel, Croll, and others, another element of astronomical vicissitude is brought to bear on this question; the variation of the mean distance of the earth from the sun. This, subjected to strict calculation, would give beyond a doubt periods of greater and less cold; and alternations of greater and less glaciation round the poles. These variations would occupy long periods of time (expressed in thousands of centuries), and by combination with the shorter periods of analogous changes pointed out by Adhemar, would sometimes be greatly augmented, and at other times greatly diminished, in effect. The oscillations thus to be occasioned have been calculated; the effects are real; they may be very influential on climate; but they are not sufficient, nor indeed well fitted, to explain local changes of level amounting to 1000 or

1500 feet in certain parts of the north temperate zones; much less would they account for the vertical up and down movements of older periods in the world's history of ten times this amount[a].

Assuming then, according to the general consent of geologists, a constant or but slightly variable sea-level, we find the following results.

1. During the whole eocene period the area which is now the basin of the lower Thames was undergoing depression, so as to have received 500 or 600 feet of sediments upon the chalk floor, which had been previously worn by waves and currents at small depths, and drilled by resident boring shells. This movement must have extended far beyond the Thames drainage; in the basin of Hampshire it must have measured vertically some 1500 feet; yet between the two basins it is thought the anticlinal of the weald may have been rising and delivering detritus both northward and southward. If so, the movement, though perhaps due to a general subterranean cause, must have had local determinants which theory may possibly discover.

2. During meiocene and pleiocene periods it may be believed that the Tamisian area was undergoing re-elevation, because the crag deposits of the eastern coast, the latest pleiocene known in Britain, are found to have been deposited for the most part in shallow sea-water, and unconformably with reference to eocene strata 400 or more feet above their level. At the close of the pleiocene period, as represented by the crag, the general level of the island must have been nearly what it is now, for the crag is only elevated a few feet above the sea.

3. But again depression took place; for first, in the crag district, beds of fresh-water shells, and a 'forest bed' a little more recent in date than the crag, and formed at a level somewhat below that bank of shells after its elevation, are followed and covered up on the Norfolk coast, near Cromer, by an hundred or two hundred feet of boulder clay and gravels associated therewith, which contain some bands of marine shells, and many marks of marine action, and probably ice-floating on a wide and deep sea. In the district round Oxford, we may satisfy ourselves that this

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[a] It is chiefly with reference to climate that Mr. Croll has so well employed the astronomical considerations referred to. See Phil. Mag. and Annals.

depression was enough to bring sea-water and its drifting movement over all but our highest hills in the chalk and oolite ranges. It may have covered those highest hills, but proof fails at 750 feet, according to the careful researches, which I am happy to confirm, of Mr. Hull[b] and Mr. Lucy[c]. Elsewhere, as in Wales, on the western border of Derbyshire, in Yorkshire, round the Lake district, in Scotland, and in Ireland, the proof goes to 1500 feet; and the supposition of a merely local cause for so general an effect is speedily exchanged for an admission that it extended very widely round the region of the Baltic and North Germany, producing everywhere a cold, even glacial sea.

4. This remarkable phase passes; the whole country rises again, and takes so nearly its ancient position that the pre-glacial forest-bed is found at about half-tide level on the eastern coast of Norfolk, just as on the eastern coast of Yorkshire marshes, lakes, and forest-beds of post-glacial, prehistoric, and historic date are found and formed at this day.

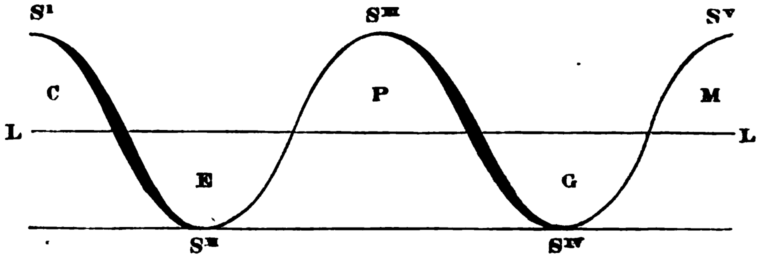

Diagram CCVIII. Upward and downward movement.

If we represent by horizontal spaces the flow of geological time from the era of chalk *C* to the modern epoch *M*, and by a continuous curve the elevations and depressions which are admitted to have happened with reference to the sea-level, the result will be such a diagram as that given above. The letter S^{I} being taken to represent a certain point on the earth's surface, above *LL* the level of the sea (where the first depression began after the state of previous elevation of the chalk), this point would be found depressed to S^{II}, re-elevated to S^{iii}, sunk again to S^{iv}, and finally restored to its original level at S^{v}. *E* would represent an eocene basin, *G* a glacial basin, separated in point of time by *P*, pre-glacial, if not also pleiocene and meiocene land. S^{v} is our present condition—one, as it appears, of elevation, which perhaps in a space of time sufficiently long may be exchanged for depression.

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[b] Proceedings of the Geol. Soc. 1855.

[c] Proceedings of the Cotteswold Club, 1869.

These remarkable and extensive oscillations, by upward and downward movements of the land within certain limits, and several times repeated, are difficult to explain by any theory concerning the condition of the earth's interior masses. One might frame another explanation, by supposing a limited sea at a different level from the main ocean, and subject to variation of level by change of boundary and other causes; but this helps us little, for the production of such a variable sea implies earth movements not less difficult of explanation than the others, and more complicated in operation.

We are not, however, now concerned with theoretical explanations of the movements; such investigations cannot be conducted on so narrow a basis as even the islands of Britain, much less on the basin of a single river. Let us therefore turn to trace the effects of these movements, which must be admitted as real and effective in altering the surface of the country under review.

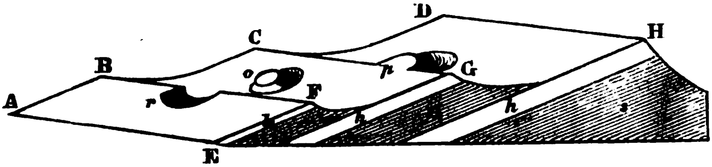

Diagram CCIX. Waste of the Earth's Surface.

Let *A, B, C, D, E, F, G, H* be a mass of stratified matter, partly firm and coherent rock, as *h*, and partly softer matter, as clay; the whole raised above the sea, so as to have a uniform inclination from *D H* to *A E*. It will be found as a general rule that hollows formed in the clays run between escarpments formed of the rocks. In the oolitic districts the slope to the right below *H* is on lias clay; that below *G* is on Oxford clay; that below *F* is on Kimmeridge clay. These hollows and escarpments extend for twenty, forty, or more miles, and the explanation which seems most probable is the following:—Conceive the rising of land in the direction described to have been gradual, and angular, so that first the parts about *D H*, next those about *C G*, and finally those about *B E*, appeared above the water. The effect would be some degree of waste on every part by the action of the troubled sea along every freshly presented line of coast; the softer parts would be wasted in a higher degree, and through greater depths of water, so as to form the hollows in question. Irregularities would arise, projections as at *p*, recessions as at *r*, outliers as at *o*. The firm rocks might have continuous plane surfaces of considerable extent, so that a given bed of stone, of no great thickness, e.g. cornbrash, might occupy the ground for a mile or more in breadth, and for ten or twenty or more miles in length, without a particle of Oxford clay resting upon it; though in other places outliers of this clay might appear in small patches dotted on the stony slope.

There can be no doubt about the truth of this reasoning; but something further is to be stated. The rising of the land above the mean level of the sea is a measure of great mechanical energy: under such an effort the rocks are strained; they yield unequally among themselves, unequally and in various directions at different localities in the area subject to elevation.

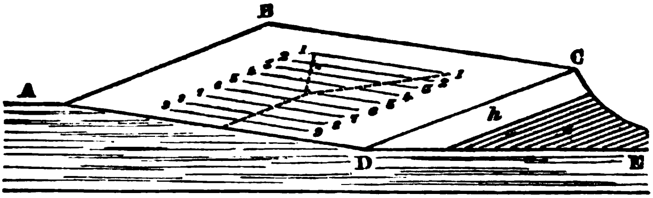

Diagram CCX. Waste of the Earth's Surface.

1. Let *A*, *B*, *C*, *D* be a tract of stratified rocks, (*h*) hard, (*s*) soft, elevated above the sea-level *A*, *D*, *E*. In this tract, in consequence of the movement of elevation, let there be lines of weakness arising from partial discontinuity of the masses (whether produced by faults or not), as represented by dots.

2. Let the movement be supposed at an end, the country settled, rain falling. The rain will enter the ground more freely on the lines of weakness. It will *flow* in the direction of these lines

in proportion to their inclination, and thus will waste the rocks in those directions underground more than elsewhere. It will also in some degree waste the surface more in those directions, because of the convergence of the small rain-streams thither. Thus continuous hollows, small valleys in short, will be produced over many parts of the surface, with a tendency to converge to the directions of least continuity and least resistance in the masses of the rocks.

3. Let the rocks be calcareous. In this case the rain-water, by means of the carbonic acid which it brings, will dissolve the rock along the subterranean fissures and channels. This action will be accelerated by the additional solvent power imparted to the water by decomposing vegetable matter in the soil. The whole surface of the country will undergo slow dissolution; carbonate of lime and carbonate of magnesia will be carried downwards, to be delivered in the springs, or else in particular places to be separated and deposited as stalactite, stalagmite, &c. Phosphate of lime, sulphate of lime, chloride of sodium, &c. are also dissolved out of many rocks by the rain.

4. This process continued through a very long period of time must necessarily cause subterranean channels and cavities along the course of the descending streams: in the lapse of time the roofs of these channels, weakened and unsupported, fall in, and the series of caverns becomes a rugged cliff-bordered vale, such as are common in the great limestone districts of Yorkshire and Derbyshire, where they may be seen in progress of extension; and in the Mendip hills, where, as at Wokey-hole, the ancient channels are partly choked with bones and mud and partly swept clear by the strong underground stream.

5. If the rocks be not calcareous the effect is different; they are not dissolved, but fretted away by the sandy matter suspended in the stream: and this is observed much more about the surface, especially in countries where the rocks are argillaceous, than in the interior. But where the line of weakness is determined by a 'fault,' that divisional plane is usually marked by the free passage of water and its mechanical and chemical effects. In the lines of such faults mineral springs frequently arise.

6. These things, now put as depending on the supposition of an elevated tract of strata, are perfectly real, and are in daily

operation. Taking the upper Thames for our example, and allowing, according to several analyses, twenty grains of salts dissolved in a gallon of the water, we find this to represent about $\frac{1}{3500}$th of the weight; and allowing the specific gravity of the salts to be twice that of water, it will represent $\frac{1}{7000}$th of the volume of water. The depth of river-water (about one-third of the whole quantity of rain) being 9 inches[d], we have for the annual waste of the upper Thames area $\frac{9}{7000}$ths of an inch; so that in less than 800 years our whole area will be lowered by surface-waste one inch. Not wasted equally, nor wholly at the surface, but on the average, and really wasted to that extent. And thus hills and valleys are in course of continual modification, and thus their peculiar features may have been produced[e].

We may next trace the operation of the sea on the same tract of land *A, B, C, D,* on the supposition, which no one will now dispute, of the gradual and successive uncovering of the rising land. In this case the parts successively exposed are, each in its turn, exposed to the action of the sea, rising and sinking, rushing in currents and falling in breakers, and moistening with foam. The lines of weakness are thus thoroughly explored by the searching waves, and experience more than other parts the wasting power of moving water, and the grinding effect of sands and gravels which it drifts along its course.

First at 1 we may conceive, then at 2, 3, and so on in succession, all parts of the surface, beginning at what is now highest, must yield more or less to the strong attack of the sea; and yield, probably, so much the more as the attack followed instantly on each change of position, when the disturbing effect of the upward movement must be supposed the greatest. The result would be valleys of the same general character as that already ascribed to valleys of erosion by rain. In each case erosion by water.

There would be a difference of some importance in the case of calcareous rocks, for though the sea would act both chemically and mechanically on limestone, this would not, probably, occasion long underground channels and caverns; though if such existed before, it would in a remarkable degree tend to break down the weakened roof and convert the channels into rugged valleys.

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[d] See p. 46 for the evidence of this.

[e] I find by a communication of Mr. Clutterbuck, that he allowed 100 grains of carbonate of lime in one cubic foot of water flowing from the chalk in the river Gade, near Watford.

Let us view this interesting subject under a third aspect: let the same tract *A*, *B*, *C*, *D* be supposed to sink gradually, as all geologists admit to have happened in very many cases and over very large spaces. The effect will, obviously, be felt successively on the lines of successive sea-level, where the oceanic battery is strongest; first at 10, then at 9, 8, &c., till the highest point is reached by the water.

Thus the whole surface will be in some degree wasted, and the waste will be greatest on the lines of weakness, so that by this process valleys must be occasioned, much as in the case of the land rising. If the land neither rises nor falls, only the sea-coast line and the sea-bed to a small depth are worn away. This effect is quite different on different coasts, especially by reason of pebbles and fragments drifted over the bed, by which it is ground down, often to a nearly level surface.

The origin of valleys, then, dates from the first elevation of land above the sea; and nature is still engaged putting her last touches to landscape by the daily action of heat and cold, rain and rivers, snows and glaciers. All parts of the surface have been wasted, all high parts are still undergoing abatement and waste; the most coherent parts, those capable of most resistance, suffer the least or rather the slowest decay, and often remain as monuments to mark how great has been the mass of earth removed from around them. In this point of view the Matterhorn stands up a melancholy pyramid among the crests of the Alps, like a broken column surrounded by the ruins of an Eastern city, but with this difference—Man 'makes a solitude and calls it peace[f],' while Nature converts slow decay into perpetual beauty, and gives the spoils of the Alps to fertilize the valleys of Switzerland.

Applying this theory to the higher valleys of the Thames, and taking up first the general view of atmospheric action on a surface which had previously been rough hewn and broadly shaped by internal movement and wave action, we may speedily be satisfied that the uppermost of the Cotswold streams are still undergoing modification of their principal surface-features from the ordinary effects of rain and snow, heat and cold, chemical and mechanical agencies. Whoever will stand during a heavy thunder-shower on the high land about Broadway or Birdlip, will require no further evidence as to the power of falling rain to disintegrate the soil and small stones, and move them little by little down the slopes. In a few minutes a cyclonic storm may even clear away those materials and expose the native rock.

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[f] Tacitus, Vit. Agric.

The hollows towards which they are, however slightly, urged, though usually quite dry, and without trace of a channel, may on such occasions be swept by short-lived currents; and by a repetition of these processes in a long period of time, the whole surface will be lowered, and the waste be insensibly transported farther down the valley. Insensibly, until we reach in descending the hollow the region of springs and brooks. Even here the removal of waste is almost insensible, since, except in particular cases, the streams carry no stones—only transport fine sediments in suspension, or roll small particles for small distances on their beds.

But it was not always so. Flat meadows, formed by water settling to rest and depositing sediment, appear on the sides of the stream, and occasional gravel patches at their margins mark the former force of stronger currents; and when we pass downward to the region of the Thames proper, the great receiving drain of the country, the Cotswold stream flows amidst broad tracts of pebbles which a more powerful river, rushing down the same valley and subject to greater floods, deposited in the broad hollow which had been filled by the sea at some earlier time.

When was that gravel deposited? The answer must be—after the last submersion and re-elevation of the tract where it lies. For though gravels may have been formed in abundance in earlier periods, none such could have remained lying as these lie, undisturbed by the rises and falls of the sea. By so much as the amount of this gravel, and the finer sediments transported farther on or carried to the ocean, have the higher grounds been wasted and lowered in the course of the period which has elapsed since the water, thought to be a cold or glacial sea, flowed over all but the very highest of the Cotswold Hills.

What is the length of that period, the latest of the steps in the long scale of geological time? It is hard to say, because it is difficult to find reliable evidence. When we stand by the conical mound of La Tiniere, left where the brook quits its mountain channel to fall into the Lake of Geneva, and mark the layers of which it is formed, some below and some above the dispersed reliquiæ of Roman occupation, we can form a probable estimate of the time employed in the accumulation of the whole, by the admissible evidence of the time which has elapsed during the accumulation of a part. Out of that mound, far below the Roman line, there was taken in my presence, and under the eyes of my companions, Mr. J. E. Lee and the late M. Morlot, a portion of the cranium of a man, whose life-date might be stated to have been some thousands of years before the palmy days of imperial Rome.

But here in our valleys no such marks occur; our Saxon, Roman, and British remains are never buried beneath layers of the gravel, but always lie on its surface or in holes dug into it for burials, wells, or dwelling-places. These gravels, then, are more ancient than all known human occupation; perhaps more ancient than even that dimly understood period which we call pre-historic, marked by the flint implements of early or even the earliest date, since we have not in this part of the Thames drainage yet found these implements deeply imbedded in the gravel by natural operations.

Some long interval of time undoubtedly separates us from the latest of the broad gravel-beds in the upper valleys of the Thames; the formation has practically ceased for thousands of years; the physical conditions of the country have changed. What were the conditions when the gravel was transported down the valleys of the Thames?

Gravel is no longer accumulated, except in very small quantities, because the water-forces exerted in the valleys are unequal to transport it. The uplands are still wasted, and plenty of small calcareous stones lie on the slopes, such as might make gravel-beds; but the rain and snow are less abundant, and the floods less impetuous. The velocities of the existing currents, even in flood time, would be quite incompetent to move the larger sort of ordinary gravel, much less the large flints, larger corals, and greater masses of rock which occasionally appear in the midst of these irregular strata. To move some of these large masses would seem to require the agency of shallow ice-rafts, formed in the valley (not ice-bergs drifted from afar), because they lie not at the bottom, but in the midst of or at the top of the gravel, which could not be the case if water-streams had urged them, for then they would have been on the bottom.

Illustrations of both processes occur near Oxford. At Yarnton, where below some 12 feet of ordinary local, mostly oolitic, gravel, lay a separate bed, about 18 inches thick, of large rolled stones of the 'northern drift;' and on this bed were found most of the numerous teeth and tusks of elephants which occurred there.

On the other hand, at Long Wittenham, a block of 'sarsen' stone, 4 feet 6 inches long, was found in the upper part of the ordinary flood gravel; a good example of ice-transported stone.

Thus we are conducted again to the contemplation of a time when this region was subject to greater extremes of cold than now, with more abundant rain and snow—a *pluvial* period—after the last retreat of the great waters; and it is permissible to believe that the local climate has been gradually improving and acquiring more of its insular mildness and comparative dryness from that day to this, when fears, not founded on accurate registration, however, are occasionally expressed that the annual rainfall in our country is sensibly and injuriously diminishing.

CHAPTER XX.

ECONOMICAL QUESTIONS.

COAL.

THE mineral substance most precious to mankind is so abundantly exposed to observation in Britain, so well situated for working, and so accessible to all parts of the empire by rail and water, that for some hundreds of years no anxiety need be felt as to the 'duration' of our coal-fields, though the best quality of fuel may command increasing prices and come sooner to an end.

Beyond the area of coal actually known by observation, a large additional tract, as yet unexplored, is confidently marked out for future working, on the eastern border of the continuous field of Yorkshire, Derbyshire, and Nottinghamshire; and inferences more or less favourable of some possible extension apply to several of the detached carboniferous tracts in the midland counties. These inferences, gradually strengthened by limited experiments near Birmingham, Nottingham, Nuneaton, and Charnwood Forest, have been combined of late years with some remarkable purely geological views, especially by Mr. Godwin Austen[a] and Mr. Hull[b]. To the former we are indebted for a comprehensive survey of the probable boundaries of the old coal growth, and the effect of subterranean movements under the east and south of England, invisible at the surface, but not undiscoverable by good reasoning; to the latter a well-considered inference, if not a positive conclusion, regarding the thickness under the same district of the strata which usually overlie the coal.

It is sometimes argued that geology has only recorded and arranged the experience of miners; if so, it ought not to be reproached as unreasonably speculative. If it has only given back to the children of labour the laws derived from their toil, this science would deserve more of the attention of those who direct mining operations than it actually receives. It has indeed already stopped many foolish trials for coal where no good result could be expected; it has retarded, at least, experiments as yet too hazardous; and it has encouraged efforts which have been successful beyond the miner's hopes, and even contrary to his expectations. It may be believed that we have passed the days (we are certainly fast losing the memory of them) when the borings or 'coal-pits' of Bruham and Radley, and Brill and Northampton, and Easingwold and Whitby, excited the ridicule of Smith and Conybeare, and Buckland and Murchison, and brought heavy expenses on innocent landowners; but we have hardly reached the epoch when an English county will shew so much confidence in the attainments of science as to undertake the costly and persevering operation of penetrating the earth to a depth of 3000 feet in a locality deliberately chosen by thoughtful geologists. Perhaps the evidence taken by the Commission on the extent of our coal-fields may place this great subject in a truer and more favourable light.

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[a] Geol. Soc. Proc. vol. xii. (1856).

[b] The Coal-fields of Great Britain. The second edition, 1861, contains a useful map.

Mr. Austen's remarkable Essay traces the probable continuation of the long, narrow Westphalian and Belgian coal-field lying north of the Ardennes, by Calais to the basin of the Thames and the Kennet, from whence, perhaps with interruptions, the line may be carried on to Somerset, South Wales, and Ireland. Everywhere, as far as can be seen, there is on the south of this line an anticlinal elevation of a date posterior to the formation of coal.

Since the publication of his memoir, a remarkable discovery by boring has been made at Harwich, where, after passing through the cainozoic and cretaceous deposits, the auger penetrated a rock which appeared to be of the nature of carboniferous shale, and contained in oblique laminæ a specimen of Posidonia, such as occurs in strata of the upper palæozoic age in North Devon. If a line be drawn from Harwich,—necessarily a line of disturbance,—parallel to that already traced south of the Thames basin, it will cross the midland counties and pass by the Malvern Hills to the centre of Wales, and leave on the north all the known fields of midland coal. Such a line of deficiency of coal on the north side of the

London basin is hypothetical, but not wholly to be rejected, because movements of great length in the periods following the coal measures, some running north and south and others east and west, were seldom single, but usually marked by several ridges and hollows, which on a great scale were rudely parallel.

According to this general view, then, the modern basin of London, or the southern part of it, may have beneath it from end to end a disturbed, probably narrow, system of coal strata, the quality of which may be conjectured, from its place between the Belgian and Welsh strata, to be good. Is it accessible? at what probable depth?

Here we come upon the researches of Mr. Hull in respect of the thickness of beds usually covering the coal. By his examination it appears that the thickness of these beds, in a general sense, grows less and less as we proceed to the eastward and south-eastward from the midland coal-fields; and this to an extent which must be regarded as very important practically. The Permian strata, in some places a thousand or more feet in thickness, are in other parts not so much as a hundred.

The new red deposits, which probably exceed 1000 yards in Cheshire, and 500 yards in the country near Birmingham, are thought to be not more than 200 yards thick in the vicinity of Warwick and Stratford. The sections given in this work, Pl. III. and Pl. IV., shew how greatly attenuated in the eastern direction are the liassic and oolitic deposits. The lias, probably 1000 or 1200 feet thick in the Vale of Severn, dwindles to about 400 feet in the Vale of the Cherwell; and the Bath oolites are reduced from 500 feet near Cheltenham to 100 feet in the country near Oxford. It must follow from these data that coal measures, if they exist, would not be situated at an inaccessible depth in the country north of Oxford; but there is no good reason for selecting that or any other situation in the upper drainage of the Thames for an experiment, excepting that there the upper oolites and chalk are not to be encountered in the sinking.

IRON.

Three bands of iron-ore occur in the country round Oxford, each rich enough to be worked for small spaces, neither so continuously productive as at present to bear comparison with the abundant 'yield' of Northamptonshire. The oldest and most extensive has been explored in the marlstone, below thin upper lias shale, in the Vale of the Evenlode—at Fawler, near Charlbury, on the property of the Duke of Marlborough. It corresponds in geological position with the famous and valuable bands in the hills above Middlesborough and Guisborough in Yorkshire.

This stone, opened since the notices on p. 115 were written in several places in the Vale of Cherwell, as Claydon, Adderbury, King's Sutton, Aynhoe, and Steeple-Aston, has been found rich enough in iron to be worthy of the attention of the great works in Staffordshire and South Wales. In many pretty large areas, especially on the western side of the vale, it lies near the surface and can be wrought by open cutting very economically. In some tracts which are thus situated the stone, having been long exposed to atmospheric influences, is broken up horizontally into thin beds, and the upper parts have lost portions of the soluble carbonate; but in other places, where a thin clay bed of the upper lias covers the rock, this does not happen. There the whole mass of the 'marlstone' with its several bands of shells is solid, and all rich enough for the furnace.

The most important work at present in hand, at Adderbury, shews an open front of some hundreds of yards, only inferior to the great escarpments of Esten-Nab and Upleatham in Yorkshire. The rock is eleven feet in thickness, partly blue, or green within the large blocks, often compactly ferruginous in the joints, traversed by brown veins, and in substance finely oolitic. No part appears to be magnetic. Shell bands run irregularly through it, mostly formed of Rhynchonella tetraëdra, with sparry interiors. Vertical joints filled with clay, running north and south, divide the beds, and between these the rock has the appearance of having been tilted, so as to make frequent parallel waves above a foot high. These appearances are observed under a clay covering with a thin course of stone containing more than elsewhere Ammonites communis. In other parts of this extensive work the same bed is less solid, but equally rich. Where most productive the yield may be reckoned at about 30,000 tons to the acre; every three tons of the best samples producing one ton of iron. The poorer parts, on account of the carbonate of lime which they contain, are useful in the furnace as 'limestone.' Below the iron-stone is a grey calcareous, sometimes sparry stone, slightly ferruginous, fit for building, a purpose in which the iron-stone is commonly and advantageously employed.

The agreement of this rock with the iron-stone bands which lie upon the laminated marlstone of Yorkshire is obvious. As we proceed northward, through Northamptonshire and Rutland, more of these subjacent beds come into the series, the whole thickens and becomes even more fossiliferous, but without increasing the proportion of iron.

The next in order of time is a thinner and less regular, but in places rich band, resting on the upper lias, and corresponding in geological position to the Northamptonshire ore and the rich bed at the base of the Inferior oolite in Rosedale, Yorkshire. Beyond Northamptonshire the occurrence of this valuable bed is variable, till we reach the country about Castle-Howard and Thirsk, Rosedale and Whitby. This ore has been already described as it occurs at Worton (p. 145).

The third band is on the summit of Shotover, and if all the iron oxide, so abundant there, could be made available in the furnace, it would be valuable. But much of it is silicated, and all scattered about, except a limited ochraceous deposit of oolitic or pisolitic texture, beyond the summit of the hill toward Shotover House (see p. 414). This is only exhibited for a small space, and on that account must not be added to the other inducements for disfiguring the still delightful monticule of 'Chateau vert,' if that be the true etymon for Shotover. Abundance of iron oxide on the parallel of these Shotover sands is mixed with the sands of Buckinghamshire and Bedfordshire, but it is not in a condition for the furnace.

The scarcity of iron-ore in Staffordshire and the growing demand from South Wales may lead to a great extension of the iron-stone diggings; and it ought to be no matter of regret that coal is not likely to be extracted here by pits, or brought by railways to feed blast furnaces in the green dale of the Cherwell

STONE.

Oxfordshire, though a stony district, containing lias, oolite, and chalk with flints, is obliged to import building-stone from Bath, flagstone from Yorkshire, slate from Wales, road-stone from Nuneaton, and paving-stones from Charnwood Forest, in addition to the large supply of quartzose pebbles which are gathered from the surface and found useful in the streets. The use of all these varieties of stone is quite modern, the effect of railways and canals. Stonesfield still supplies a little of oolitic flagstone rather than slate; the roads are still mended to a considerable extent by some of the native rocks; and better stone, for durability at least, than that of Bath, is still quarried in the neighbourhood of Burford. Oolite of inferior reputation is common enough in Oxfordshire and Gloucestershire; and lime is everywhere to be obtained at short distances and moderate cost, though not of any special reputation.

The map, Plate II., shews the distribution of gravel near Oxford.

BRICKS, TILES, POTTERY.

All the clays in the oolitic series of strata are fit for making bricks, tiles, pipes, and ordinary pottery, if sand be added to the tough argillaceous element, and this is seldom far to seek. In the lower cretaceous rocks the gault, and in the supra-cretaceous deposits the Woolwich clay, London clay, and brickearth of later geological date, supply abundance of material for the kiln. An unusual process is followed in the case of the last mentioned clays at Gray's-Thurrock and other places, where the clays are mostly very sandy. The chalk, which is often dug in the same pit, is ground fine and mixed with the clay, 'to strengthen it.' The heat-action of the kiln not unfrequently appears sufficient to compel the formation of silicate of lime by fusion, and produce clinkers; but by employing moderate firing this does not happen, and the bricks sometimes appear softer and more sandy than in the districts of oolite, lias, and red marl.

OCHRE, FULLER'S-EARTH, GLASS-SAND, AND POTTER'S-CLAY.

'Among such earths as are found in Oxfordshire and are useful in trades,' says Dr. Plot, 'the ochre of Shotover no doubt may challenge a principal place, it being accounted the best of its kind in the world; of a yellow colour and very weighty; much used by painters simply of itself, and as often mixed with the rest of their colours.' It is still good of its kind, but the demand is not such as to maintain its former commercial value. Associated with the ochre are some argillaceous bands which are of the nature of fuller's-earth, and white and yellow sands. The white sands in the hill above Hartwell have been used with success in glass-making. Tobacco-pipes were made commonly during the siege of Oxford from a bed of white clay which lies above the ochre of Shotover; and the substance was of use to statuaries for making 'models, gargills or anticks,' and polishing silver, so says Dr. Plot.

Fuller's-earth was formerly dug in the Vale of the Cerne to supply the wants of the clothiers of Gloucestershire, but modern chemistry has driven the natural product out of its only market.

WATER.

Water composes half the weight of the food which we call solid; we add for drink as much in weight as that food: how essential, then, to our pleasure, comfort, and health that the element should be wholesome. It seems not necessary, perhaps it may not be desirable, that the water we drink should contain no salts of lime, or magnesia, or iron, or soda; but it must not have these in large proportion unless employed medicinally. Carbonic acid is pleasant, and perhaps useful; but organic impurity, even in small quantity, is extremely injurious, and acts as a poison.

To stand by the rocky cradle of a great river—

> 'Ad aquæ lene caput sacræ,'

and consider the eventful course of the life of the new-born stream; to see it burst exulting from leafy shades into freer air, and follow it sweeping into larger valleys and broader plains, is at once delightful and instructive. Yet not more pleasing or instructive to contemplate the full outrush of the young Danube, than to look upward and downward from Trewsmead along the solitary valley in which no drop of water is usually seen at the traditional fountains of the Thames.

Here in former days the Roman legionaries halted to slake their thirst at the perennial stream which had been for long ages before the resource of the shepherds and warriors of the Dobuni and earlier races; and it has been reserved to our own days to extinguish

ERFIELD LI OF ANCIENT HISTORY

the natural flow of water by the artificial force of steam and the authority of Parliament[c].

But a different feeling oppresses the mind when we see the once clear stream stagnating in marshy flats, polluted with decaying vegetable substances and animal products, and bearing slowly along the floating bodies of dead and dying animals. This may happen in countries not controlled by man. But under his guidance, cloth-mills, paper-mills, bone-mills, tan-pits, and factories of manure, pour their waste or wealth of dyes and chemicals into the river, which is afterwards called upon to supply one element of life to growing towns and prosperous cities. If against the ill effects of this contemptuous treatment beneficent Nature did not strenuously contend, did not earthy sediments fall by gravity, and organic masses become broken up by minute water scavengers, or dissipated by 'eremacausis,' the race of river-dwelling men must soon perish with cholera or typhus.

But is it much better in places which, like Oxford, drink the water of their own wells? The deep bed of gravel which makes the foundation of the higher parts of this city, furnishes clear water at almost every point where a well can be sunk; and it hardly ever happens that these are dried. Before so many wells were sunk—one to almost every house in the more favoured parts of Oxford—natural springs of considerable strength discharged the overflow of the never-ceasing supply which, falling in rain or melting in snow, filled the gravel from Summertown to the Quadrangle of Christchurch.

One of these, still flowing on the western side, and another, formerly discharging on the eastern side, were perhaps the greatest of these springs—truly 'Holy Wells;' but the edge of the gravel-bed resting on the Oxford clay was everywhere discharging, and still is in many places delivering, feeble supplies of moisture to the pastures, and nourishing rushes, Caltha palustris, Cardamine pratensis, and other damp-loving plants.

The water so issuing by natural orifices was not pure in the chemical sense; it contained much carbonate and some sulphate of lime gathered by the rain in its percolation through the calcareous gravel and its slow current on the subjacent clay. But it was not otherwise contaminated. On the contrary, at present, wells in Oxford, not a few, are justly to be objected to as injured by soakage of filthy solutions and mixtures from sources at the surface too near the wells. Such solutions may be expected to pass in the porous gravel even to considerable distances, and to exhibit themselves in the wells, and give proof of their existence, not only by reaction on chemical tests, but by injurious effects on the whole process of digestion.

---

[c] The Thames and Severn Canal, authorized by Act of Parliament in 1783, passing very near to 'Thames-head,' in the thirsty oolitic rocks, has supplied itself by a deep well and powerful pumps which have drained the natural source.

On this account the ancient method of supply to some of the colleges from the Hinksey springs was to be commended, though the water was hard, that is to say, charged with carbonate of lime. The modern method of supply from the Railway Lake, which is filled by nature after filtration through the gravel in the bed of the valley, is still better; but it is to be regretted that houses and offensive drains have been permitted to usurp a place too near the source which ought to be above all suspicion.

Want of water is not seldom experienced in some parts of the country round Oxford in particular seasons. This happens not uncommonly on the line of the Forest marble clays, where shallow wells are feebly supplied from the thin clay-bedded stones, and in the broader tracts of Oxford and Kimmeridge clays, which, if not covered by gravel, have no permanent natural springs. The usual remedy, 'to sink deeper,' is not always successful in the first case, because the great oolite below allows water to pass away freely by particular channels to certain favoured localities probably at some distance; and in the other case, either no water is met with, or it is scanty and of bad quality through admixture with sulphates of lime and iron, and perhaps magnesia. If, in this difficulty, the sinking be continued till the clay, however thick, be penetrated, and the subjacent oolite be reached, it is very probable that a moderate supply will be found, and that the water will rise in the well, and fill it as a convenient reservoir, or even overflow with some force. Thus an 'Artesian' well may sometimes be had; but no one should undertake the trial without good advice, of a practical geologist acquainted with the district[d].

---

[d] The Rev. J. C. Clutterbuck, M. A., of Long Wittenham, possesses thorough knowledge on questions of this kind.

The water obtained by Artesian wells, it must be remembered, falls on the surface of the rock, which, being 'tapped' underground, yields the supply. If the receiving ground be narrow and interrupted, as in the case of the Oxford oolite generally, or broken by faults, as most of the oolites are, the underground supply will be very limited, or else very unequally distributed—here excessive, there scanty.

Yet, after making these allowances, the process of boring for deep-seated water is much to be advised, the supply being usually constant, the quality good, though commonly a little hard. The enormous quantities of good water daily pumped from the chalk under London—the gift of rains and snows on the hills of Herts and Surrey—present one of the most impressive examples of the process by which nature keeps perpetually full the subterranean rifts and other cavities in the calcareous rock. These cavities are undergoing enlargement by means of the currents occasioned by the powerful steam-pumps, and the reservoir becomes more and more capacious. The interior becomes more and more hollow under London, and more and more water is demanded and obtained; yet it is not probable that the bridges will fall in our time, or that the metropolis will ever compel so much water from the shrinking wells as to dispense with the Thames and leave it to be contaminated and productive of disease and death.

If indeed there should be, according to some popular notions, either a reduction of the annual rainfall, or a diminution of the perennial springs of the Thames, by more rapid discharge of flood-water and more effective surface drainage, some other scheme must be considered.

The whole supply which now passes by Oxford in ordinary weather (see p. 46), is only equal to the quantity which London consumes; and water, like coal, is more freely used and wasted than formerly, for old and new purposes, and will be continually in greater and increasing demand for work, health, and ornament, so that the thirsty metropolis will ere long drink up the river.

Instead of depending on the Thames and its branches, 'new rivers' may have to be brought from distant regions—the examples of Manchester and Glasgow may be followed; and, though not in our days, the slopes of Welsh mountains like Plynlimmon and the Berwyns may be formed into reservoirs, and the midland counties of England be traversed by aqueducts grander than any which span the plains of Provence or the Campagna of Rome.

The preceding observations shew geology in such close relationship to the economy of daily life and the exercise of professional judgment, that it becomes a question whether the educational course of the chemist, agriculturist, miner, metallurgist, or engineer can be regarded as complete, or even sufficient, without a considerable amount of geological teaching. A geologist, as such, ought perhaps to be so much engrossed by study of the philosophical bearings of his great subject, as to be unable to acquire practical experience in any of these walks of life; but, on the other hand, he may be competent to give useful advice in each of them, founded on general principles, which may prevent many misfortunes. In this sense geology may in some degree become a professional exercise, and furnish another proof of the fruitful character of all the branches of natural science, none of which, whether they relate to rocks or fossils, minerals, plants or animals, the phænomena now passing before our eyes, or those which ceased thousands of ages gone by, can be strenuously followed without leading to many discoveries useful in every stage of society.

APPENDIX A.

DISTRIBUTION OF GENERA OF LIASSIC AND OOLITIC FOSSILS MENTIONED IN THE FOREGOING LISTS.

Names of Genera.	In preceding Periods.	Rhætic and Lias.	Bath oolite Period.	Oxford oolite Period.	Portland oolite Period.	In succeeding Periods.
PLANTS.						
Araucarites			*			
Aroides			*			
Bensonia			*			
Brachyphyllum		*				
Bucklandia			*			
Carpolithus	*		*	*		*
Confervites ?		*				*
Coniferous wood	*	*	*	*	*	*
Cyclopteris	*		*			
Equisetum ?		*				*
Glossopteris	*		*			
Halymenites			*			
Hippurites ?		*				*
Hymenopteris			*			
Lilia ?			*			
Naiadea	*		*			
Naiadita		*				
Nöggerathia ?			*			
Palæozamia		*	*			
Pecopteris	*		*			*
Pinites	*	*				*
Pterophyllum			*			
Salicites ?			*			*
Sphenopteris	*		*			*
Stricklandia			*			
Tæniopteris			*			
Taxites			*			
Thuytes			*			
Zamites			*			
FORAMINIFERA.						
Cristellaria		*	*	*	*	*
Polymorphina		*				*
Spirillina		*				*
AMORPHOZOA.	*		*	*		*

Names of Genera.	In preceding Periods.	Rhætic and Lias.	Bath oolite Period.	Oxford oolite Period.	Portland oolite Period.	In succeeding Periods.
ACTINOZOA.						
Anabacia			*	*		
Axosmilia			*			
Calamophyllia			*			
Cladophyllia			*	*		
Convexastræa			*			
Cyathophora			*			*
Isastræa		*	*	*		*
Latomeandra			*			
Lepidophyllia		*				
Montlivaltia		*	*	*		
Rhabdophyllia				*		
Septastræa		*				
Stylina			*			
Thamnastræa			*	*		*
Thecocyathus		*				
Thecosmilia		*	*	*		
ECHINODERMATA.						
Echinoïdea.						
Acrosalenia		*	*	*		
Cidaris	*	*	*	*	*	*
Clypeus			*	*		
Diadema		*				*
Echinobrissus			*	*	*	
Hemicidaris	*		*	*	*	
Hemipedina		*	*	*	*	
Holectypus			*			*
Hyboclypus			*			
Pedina		*	*			
Polycyphus			*			
Pseudodiadema		*	*	*		*
Pygaster			*	*		
Pygurus			*	*		
Rhabdocidaris			*			
Stomechinus			*			
Crinoïdea.						
Apiocrinus			*	*		
Extracrinus		*	*	*		
Millericrinus				*		
Pentacrinus		*	*			*
Asteroïdea.						
Acroura		*	*			
Astropecten				*		*
Ophioderma		*	*			*
Ophiolepis		*				*
Solaster			*			*
Tropidaster		*				
Uraster		*				
ANNELLIDA.						
Serpula	*	*	*	*	*	*
Vermicularia				*		*
Vermilia				*		*

Names of Genera.	In preceding Periods.	Rhætic and Lias.	Bath oolite Period.	Oxford oolite Period.	Portland oolite Period.	In succeeding Periods.
CIRRIPEDIA.						
Pellicipes		*	*			*
CRUSTACEA.						
Aega		*				*
Coleia		*				
Cytherina		*				*
Eryon		*				
Estheria		*				*
Glyphea		*	*	*		*
Hippolite		*				
Hoploparia		*				*
Prosopon			*			
Scapheus		*				
INSECTA.						
See the Lists of Liassic and Stonesfield Insects, pp. 123 and 174.						
POLYZOA.						
Alecto			*			*
Cricopora			*			*
Diastopora	*		*	*		*
Terebellaria			*			
BRACHIOPODA.						
Discina	*	*		*	*	*
Lingula	*	*	*	*	*	*
Rhynchonella	*	*	*	*	*	*
Spirifera	*	*				
Terebratula	*	*	*	*		*
MONOMYARIA.						
Anomia		*	*			*
Avicula	*	*	*	*		*
Crenatula		*				*
Exogyra					*	
Gastrochæna		*				*
Gervillia	*	*	*	*	*	*
Gryphæa		*	*	*	*	*
Hinnites		*	*			*
Inoceramus		*	*		*	*
Lima	*	*	*	*	*	*
Monotis	*	*				
Ostrea		*	*	*	*	*
Pecten	*	*	*	*	*	*
Perna	*	*	*	*	*	*
Pinna		*	*	*	*	*
Placuna			*			*
Placunopsis			*	*		
Plicatula	*	*	*			*
Pteroperna			*			
Trichites			*	*		

Names of Genera.	In preceding Periods.	Rhætic and Lias.	Bath oolite Period.	Oxford oolite Period.	Portland oolite Period.	In succeeding Periods.
DIMYARIA.						
Acromya			*			
Anatina			*			*
Arca	*	*	*	*	*	*
Astarte		*	*	*	*	*
Capsa			*			*
Cardinia		*				
Cardium	*	*	*	*	*	*
Ceromya		*	*			
Corbis		*	*	*		*
Corbula			*	*		*
Cucullæa	*	*	*	*	*	*
Cypricardia	*	*	*	*		*
Cyprina			*	*		*
Cytherea					*	
Dreissena			*			*
Goniomya		*	*	*		
Gresslya		*	*			
Hippopodium		*				
Homomya		*	*			
Isoarca ?	*		*			*
Isocardia	*		*	*	*	*
Leda		*	*	*	*	*
Limopsis			*			*
Lithodomus			*	*		*
Lucina	*	*	*	*	*	*
Lutraria		*				*
Macrodon			*			
Modiola	*	*	*	*	*	*
Myacites	*	*	*	*	*	*
Myoconcha	*	*	*			*
Mytilus	*	*	*		*	*
Neæra			*			
Nucula	*	*	*	*		*
Opis	*	*	*	*		
Panopæa			*			*
Pholadomya		*	*	*	*	*
Pholas			*		*	*
Pleurophorus		*				
Psammobia			*			*
Ptychomya			*			*
Pullastra		*				*
Quenstedtia			*	*		
Sanguinolaria	*	*				*
Sowerbya			*	*		
Sphæra			*			
Tancredia			*	*	*	
Thracia				*		
Trigonia	*	*	*	*	*	*
Unicardium		*	*			
Venus			*			*
Xylophaga					*	

Names of Genera.	In preceding Periods.	Rhætic and Lias.	Bath oolite Period.	Oxford oolite Period.	Portland oolite Period.	In succeeding Periods.
GASTEROPODA.						
Acmæa		*				
Actæon		*	*	*		*
Actæonina	*		*	*		
Alaria			*	*	*	
Amberlya			*			
Buccinum ?					*	
Bulla			*	*		*
Ceritella			*	*		
Cerithium	*	*	*	*	*	*
Chemnitzia	*	*	*		*	
Cirrus			*			
Conus ?		*				*
Crossostoma			*			
Cylindrites			*	*		
Delphinula			*			*
Dentalium	*	*				*
Deslongchampia			*			
Emarginula			*			*
Eulima	*		*			*
Fibula			*			
Fissurella			*			*
Fusus			*			*
Kilvertia			*			
Littorina		*	*	*	*	*
Monodonta	*		*			*
Murex				*		*
Natica	*	*	*	*	*	*
Naticella	*		*			
Nerinæa			*	*		*
Nerita			*	*		*
Neritoma					*	
Neritopsis			*			
Patella	*		*			*
Phasianella			*	*	*	*
Pleurotomaria	*	*	*	*	*	*
Pterocera			*			*
Purpuroidea			*			
Rimula			*			
Rissoina			*			
Rotella		*				*
Stomatia	*		*			*
Tornatella	*	*				*
Trochotoma			*			
Trochus	*	*	*			*
Turbo	*	*	*			*
CEPHALOPODA.						
Acanthoteuthis		*				
Ammonites	*	*	*	*	*	*
Belemnites		*	*	*	*	
Groteuthis		*				
Nautilus	*	*	*	*	*	*
Trigonellites					*	

Names of Genera.	In preceding Periods.	Rhætic and Lias.	Bath oolite Period.	Oxford oolite Period.	Portland oolite Period.	In succeeding Periods.
FISHES.						
Acrodus		●	●			
Aechmodus		●				
Asteracanthus			●	●	●	
Belonostomus			●			
Caturus			●			
Ceratodus		●	●			●
Chimæra					●	
Ctenolepis			●			
Dapedius		●				
Ganodus			●			
Gyrodus			●	●	●	●
Gyrolepis		●				
Hybodus		●	●	●	●	●
Ischyodus				●		●
Lepidotus			●	●		●
Leptacanthus			●			
Leptolepis		●				
Macrosemius			●			
Nemacanthus		●	●			
Pachycormus		●				
Pholidophorus		●	●			
Pristacanthus			●			
Pycnodus			●	●	●	●
Saurichthys		●				
Sauropsis			●			
Scaphodus			●			
Sphærodus				●	●	
Strophodus			●			●
Tetragonolepis		●				
REPTILIA.						
Ceteosaurus			●		●	●
Dakosaurus				●	●	
Dimorphodon		●				
Goniopholis					●	
Ichthyosaurus		●	●	●	●	●
Megalosaurus			●	●	●	●
Pleiosaurus				●	●	
Plesiosaurus		●	●	●	●	●
Rhamphorhynchus			●	●		
Steneosaurus				●	●	
Streptospondylus				●		
Teleosaurus		●	●	●	●	
Testudo			●			
MAMMALIA.						
Amphitherium			●			
Phascolotherium			●			
Stereognathus			●			

APPENDIX B.

ADDITIONAL NOTICES.

FOSSILS OF STONESFIELD.

Some curious specimens occur at Stonesfield, of brown or black colour, formed of a thin uniform substance without apparent structure, spheroidal in figure, as well as this can be ascertained in their actual state of compression, and from one to two inches in diameter. Originally flexible, as it appears, they are found variously squeezed, as a thin bladder may be supposed to have been. They have usually been ranked among the fruits, but in our arrangement have been classed as eggs. Mr. Carruthers has rejected them from among plants.

CETEOSAURUS.

Additional caudal vertebræ of this animal have been discovered near Chipping-Norton, in laminated beds which appear to correspond with those of Kirtlington. A tooth of megalosaurus was obtained at the same place.

ELEPHAS PRIMIGENIUS.

At Yarnton, which some years ago yielded many remains of this animal, the deep and extensive gravel deposit has been re-opened by the Railway Company; and, as before, tusks and teeth of the mammoth have been found in the lower part of the water-drifted mass, above a rough aggregate of large pebbles. One tusk has been measured to a length of 7 feet 6 inches.

VALLEY GRAVELS.

On several occasions of late years cuttings into the alluvial deposits in the flat alluvial valley of the Thames, near Oxford, have shewn under the ordinary silt derived from floods, considerable breadths of shell deposits, containing Paludina vivipara and P. impura, Limnæa peregra, and other denizens of marshy ponds and shallow waters, and small oolitic gravel under the whole. Thus in reality we have three gravel deposits, the lowest being irregular and limited, and probably derived by flood action from the margins of older valley terraces 20 feet above the present river, not brought down by great inundations the whole distance from the Cotswolds. As yet no remains of the mammoth or his contemporaries have been found in these *lowest* gravels; whether in the larger excavations likely to be made in the valley below Oxford such may occur is very worthy of attention.

INFERIOR OOLITE.

Additional instances of the occurrence of Inferior oolite fossils in the district watered by the Cherwell and its branches have been brought to notice by Mr. Beesley, who has successfully explored the vicinity of Banbury. He finds at Coomb Hill near Barford St. John, and at Blackingrove near Barford St. Michael, a considerable number of fossils, among which Pholadomya fidicula and Terebratula fimbria may be cited as frequent in the Inferior oolite of Cheltenham. With Mr. Stutterd, whose large collection, as well as part of that of the late Mr. Faulkner, is now in the Oxford Museum, he obtains from Milcomb Hill, a locality farther west, Ammonites Parkinsoni and Pholadomya fidicula. In both localities several other shells occur which are known in Inferior oolite, but some of these are also found through such considerable ranges of the Bath oolite group, as to be insufficient though favourable witnesses. On the whole, it seems probable that these traces both of the upper and lower parts of the Inferior oolite in the region between Cherwell and Evenlode are the first steps toward a considerable extension of the space to be allotted to those deposits.

THE RED SANDSTONES. (See p. 99.)

The colouring matter of these rocks is usually in small quantity, thinly investing clear grains of quartz. The following analysis of one specimen, made by my friend Mr. Heathcote Wyndham, shews how small a proportion of oxide is sufficient to stain the stone:—

Analysis of Red Sandstone (from Ardrossan).

QUALITATIVE ANALYSIS.	QUANTITATIVE ANALYSIS.
Silica.	Silica, 96·4 per cent.
Copper (?) trace.	Iron, ·364 to ·369.
Iron.	
Aluminium.	
Calcium.	

The aluminium was in excess of the iron.

THAMES WATER. (See p. 488.)

Analysis of Thames Water collected at Oriel Barge.

Per-centage of solid matter in sample filtered from suspended matter and dried at 100°, ·02924[a] = $\frac{1}{3420}$.

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[a] This would contain the inorganic matter, calcium salts, &c., and organic matter.

INDEX.

A.

Abbay, Mr., p. 198.
Abberley, 78, 80, 85.
Abingdon, 39, 40, 44, 468.
Aborigines of Britain, 475.
Adams, Mr., 229.
Adderbury, 37, 496.
Addlestrop, 15.
Adhemar, M., 482.
ÆLIA CASTRA, 54.
Agassiz, M., 232.
Age of reptiles, 391.
AKEMAN STREET, 33, 54.
Albans, St., 443.
Allesley, 96.
Amiens, 476.
Ammonites, in zones of lias, 134; in oolites, 399.
Amorphozoa, Silurian, 74; Cor. ool., 300; Cretaceous, 432; Eocene, 453.
Amphitherium, history of opinions regarding this animal, 231; jaws of two species, 231–235.
Ampthill, 428.
Ancient roads, 53.
Andover's Ford, 15, 32, 42, 51.
Annellida, Cambrian and Silurian, 74; Carboniferous, 83; liassic, 122; Inf. ool., 158; Fuller's-earth, 166; Stonesfield, 173; Great oolite, 239; Oxf. clay, Calc. grit, and Cor. ool., 301; Kim. clay and Portland ool., 329; Cretaceous, 435; Eocene, 453.
Antiquity of gravel, 491.
Arbury Hill, 36.
Ascott, 144.
Ashdown, 446.
Ashmole, Elias, 2.
Aston, 36, 37.
— North, 51.
Astrop, 51.
AUFONAS, INTER, 54.
Aust fishes, 101, 124.
Austen, Mr., 78, 327, 493.
AVEBURY, 22.
Avelyn, Mr., 7.
Avicula beds, 114.
Avon, River, 14, 42, 43, 460.
Aylesbury, 326.
Aynhoe, 496.

B.

Badbury Hill, 424.
Bagley Wood, 460.
Baker, Miss, 246.
Baldon, 370, 426.
Banbury, 37, 115.
Barford, 37, 512.
Barnet, Mr., 247.
Barrington, 146.
Barrow-on-Soar, 110.
Bath, 113, 117, 150.
— oolite fossils, 155.
— oolite period, 137; tabular view, 138.
Beckles, Mr., 220.
Bedford, 315.
Beesley, Mr., 512.
Belemnites in zones of lias, 134.
Bell, Mr., 472.
Belvoir, 115.
Berkeley, 78.
Berrow Hill, 89.
Besselsleigh, 300.
Bicester, 38.
Binton section, 110.
Birdlip, 54.
— Hill, 17, 490.
Birds, Stonesfield, 219; Eocene, 455.
Bishopstone, 419.
Blackheath, 448.
Black shale of Malvern, 67.
Bladon, 36, 460.
Blainville, M., 232.
Blechingdon, 285.
Blisworth, 253.
BLOWING-STONE, 449.
Bloxham, 37.
Blue Wick, 118.
Bone, Mr., 236.
Bone-bed of Potton, 429.
Botanic Garden, 1.
Botley, 38.
Bourton-on-the-Water, 15, 33.
— on-the-Hill, 16.

Brachiopoda, Cambrian and Silurian, 74; Carboniferous, 83; Liassic, 123; Inf. oolite, 158; Fuller's-earth, 166; Stonesfield, 175; Great ool., For. marble, and Cornbrash, 240; Oxf. clay, Calc. grit, and Cor. ool., 302; Kim. clay and Portland ool., 329; Cretaceous, 436; Eocene, 454.
Brackleaham, 450.
Brailes, 55.
Bredon Hill, 14, 17.
Brentford, 469.
Bricks, 498.
Bridport, 196.
Brighthampton, 57, 480.
Brill, 18, 40, 326, 374, 417, 460.
BRINAVÆ, 36.
Bristol, 58, 80.
Broadway Hill, 17, 33, 54, 115, 144, 117, 490.
Brockhampton, 32.
Broderip, Mr., 6, 230, 235.
Brodie, Rev. P. B., 94, 96, 103, 124, 134, 430, 459.
Broughton Castle, 37.
Brown, Mr., 473.
Bruern Abbey, 35.
Buch, Von, 133.
Buckingham, 460.
Buckland, Rev. Dr., 4, 7, 96, 105.
Buckman, Prof., 120, 126, 134, 173, 194.
Bunter Sandstein, 95.
Burford, 16, 34, 117, 144.
Byfield, 36.

C.

Cader-Idris, 48.
CÆSAR, C. J., 15, 480.
Calcareous grit, 298, 412.
Calne, 301.
Cambrian fossils, 68.
— period, 65.
Camden, William, 24, 55.
Camerton, 85.
Canons-Ashby, 36.
CARACTACUS, 54.
Carboniferous fossils, 82.
— limestone, 80.
Cardinia beds, 114.
Carfax, 51.
Carpenter, Dr., 6, 433.
Cassian, St., 101.
Cat's-grove, 443.
Caudel, Mr., 248, 384.
Caverns, none, 16.
Cephalopoda, Cambrian and Silurian, 74; Carboniferous, 83; Liassic, 129; Inf. ool., 163; Fuller's-earth, 167; Stonesfield, 177; Great ool., For. marble, and Cornbrash, 243; Oxf. clay, Calc. grit, and Cor. ool., 304; Kim. clay and Portland ool., 331; Cretaceous, 439; Eocene, 455.
Cerney, North, 30.
Ceteosaurus Oxoniensis, 164, 332; history of discoveries, 245; plan of the reliquiæ at Kirtlington Station, 250; synopsis of bones, 252; tooth, 253; vertebræ, 254–266; ribs, 267; sternum and coracoids, 268; scapulæ, 270; humeri, 272–274; ulnæ, 275; pelvis, 276; femur, 279; tibia, 282; fibula, 283; metatarsals, 284; habits of life and magnitude, 291–294.
— longus, 390.
Chadlington, 51.
Chalgrove, 40.
Chalk bored, 442.
— hills, 20.
Chapel-House, 164, 261.
Charlbury, 52, 117, 144.
Charles I., 36.
Charlesworth, Mr., 236.
Charlton-Abbots, 32, 42.
Charnwood Forest, 460.
Charwelton, 36.
Chaselton, 55, 116.
CHEDWORTH VILLA, 32.
Chelt, River, 15, 30, 42.
Cheltenham, 115, 116, 156.
Cherwell, 16, 36, 45, 46, 139, 460, 496.
Chicksgrove quarry, 326.
Chilterns, 44, 52, 443.
Chippenham, 41.
Chipping-Campden, 115.
— Norton, 117, 164, 245, 290, 460.
Churchill, 3, 35, 51, 144.
Churn, River, 15, 29, 30, 42.
Cirencester, 25, 29, 30, 53, 153, 461.
Cirripedia, Liassic, 122; Stonesfield, 173; Eocene, 454.
Claydon, 496.
Cleeve-Cloud, 17, 32, 42, 117.
Clement's, St., 297.
Clifton-Hampden, 40, 426, 465.
Clutterbuck, Rev. J. C., 28, 467, 473, 477, 488, 501.
Coal, 493; probability of, near Oxford, 494.
— measures, 85.
— plants, 86.
Cœlenterata (or Zoophyta, or Actinozoa), Cambrian and Silurian, 74; Carboniferous, 82; Liassic, 121; Inf. ool., 157; Fuller's-earth, 166; Stonesfield, 171; Great ool., For. marble, and Cornbrash, 239; Oxf. clay, Calc. grit, and Cor. ool., 300; Kim. clay and Portland ool., 328; Cretaceous, 433; Eocene, 453.
Cole, River, 18, 33.
Cole's Pits, 425.

Colesborne, 30.
Collyweston beds, 167, 408.
Coln, River, 15, 31, 42.
Coln St. Aldwyn's, St. Denis, and Rogers, 32.
Combe Wood, 418.
Compton Park, 32.
Conybeare, Rev. Dr., 5, 105.
Coralline oolite, 299, 412.
CORINIUM, 29.
Cornbrash rock, 155.
Cotswold ('Cotteswolde'), 9, 17, 44, 460.
Cowley, 194, 307, 375.
Coxwell, 424.
Crayford, 470.
Cretaceous System, 422.
Cricklade, 24, 30, 465.
Croll, Mr., 483.
Cromer, 481.
Cropredy, 36.
Crustacea, Cambrian and Silurian, 74; Carboniferous, 83; New red, 97; Rhætic, 105; Liassic, 122; Inf. ool., 158; Stonesfield, 173; Great ool., For. marble, and Cornbrash, 239; Oxf. clay, Calc. grit, and Cor. ool., 302; Iron-sand, 414; Cretaceous, 435; Eocene, 454.
Cubberley, 30.
Cuddesdon, 253.
Culham, 8, 426, 465.
Cumnor, 16, 19, 38, 51, 300, 334, 362, 460.
Cunnington, Mr., 423.
Currents, force of, 463.
Cuvier, M., 192, 196, 230, 322, 388.

D.

Dakosaurus, 306, 389.
Danby, Lord, 1.
Dasyceps, 96, 98.
Daventry, 115, 117.
Dawkins, Mr., 472.
Dawson, Prof., 61.
Daylesford, 116.
Dean Forest, 59, 80, 87.
Deddington, 37, 145.
De la Beche, 80, 468.
Dennis, Rev. J. P., 229, 236.
Denton, 418.
DEVIL'S COITS, 57.
Dickler, River, 33, 34.
Dimorphodon, 135.
Dimyaria, Cambrian and Silurian, 74; Carboniferous, 83; Rhætic, 106; Liassic, 126; Inf. ool., 160; Fuller's-earth, 167; Stonesfield, 175; Great ool., For. marble, and Cornbrash, 241; Oxf. clay, Calc. grit, and Cor. ool., 303; Kim. clay and Portland ool., 330; Iron-sand, 415; Cretaceous, 439; Eocene, 454; Pleistocene, 467, 469, 470, 472.
DOBUNI (Δοβοῦνοι), 30, 55.
Dorchester, 40, 458, 465, 479.
Down-Ampney, 463.
Drainage, effects of, 50.
Drayton, 24.
Drift, northern and southern, 461.
Druid sandstone, 446.
Dry-Sandford, 194.
Ducie, Earl, 220, 253.
Dumbleton Hill, 14.
Duncan, Dr., 121.
DUROCINA, 480.

E.

Eastington, 33.
Echinodermata, Silurian, 74; Carboniferous, 83; Liassic, 121; Inf. ool., 157; Fuller's-earth, 166; Stonesfield, 172; Great ool., For. marble, and Cornbrash, 239; Oxf. clay, Calc. grit, and Cor. ool., 301; Kim. clay and Portland ool., 329; Cretaceous, 433; Eocene, 453.
Economical questions, 493.
Edgcott, 36.
Edgehill, 17, 36, 37, 115.
Egerton, Sir P., 101.
Eldon, Earl of, 32.
Enniskillen, Earl of, 348.
Enslow Bridge, 37, 152, 184, 216.
Eocene period, 442; sections, 443; deposits, 450.
Eozöon Canadense, 61.
Epwell, 17, 37.
Erith, 470.
Escarpments, natural, 485.
Essendine, 253.
Etheridge, Mr., 7, 102.
Evenlode, River, 15, 35, 43, 45, 139, 460.
Evesham, 45.
Ewen springs, 27.
Exhall, 96.
Eyeford, 34, 167.
Eynsham, 38, 57, 464.

F.

Fairford, 32, 153.
Falconer, Dr., 237, 472.
Falkland, Lord, 41.
Faringdon, 39, 421, 424.
Farmington, 34.
Fault, Malvern, 92; influence of, 93.
Fawler, 115, 496.
Fenny-Compton, 36, 121.
Fishes, Silurian, 74; Devonian, 79; Carboniferous, 83; New red, 97; Rhætic, 106; Liassic, 134; Inf. oolite, 164; Stonesfield, 177; Great oolite, For. marble, and Cornbrash, 244; Oxf. clay,

Calc. grit, and Cor. ool., 305; Kim. clay and Portland ool., 332; Cretaceous, 441; Eocene, 455.
Fitton, Dr., 6, 148, 231, 411.
Flint implements, 458, 475.
Foraminifera, Silurian, 74; Carboniferous, 82; Liassic, 120; Stonesfield, 171; Great ool., For. marble, and Cornbrash, 395; Oxf. clay, Calc. grit, and Cor. ool., 300; Cretaceous, 433; Eocene, 453.
Fords, 51.
Forest-bed, 472.
Forests, 52.
Foscot, 35.
FOSS ROAD, 26, 32, 35, 53.
Foxcombe, 345, 364.
Franz, Dr., 237.
Frogmill, 32.
Fuller's-earth rock, 146.

G.

Garsington, 349, 376, 380.
Gasteropoda, Silurian, 74; Carboniferous, 83; Liassic, 127; Inf. ool., 162; Fuller's-earth, 167; Stonesfield, 175; Great ool., For. marble, and Cornbrash, 242; Oxf. clay, Calc. grit, and Cor. ool., 304; Kim. clay and Portland ool., 331; Iron-sand, 415; Cretaceous, 439; Eocene, 454; Pleistocene, 467, 469, 472.
Geological revolutions, 481.
Gloucester, 115.
Glyme, River, 36.
Glympton, 36, 247, 261.
Gneiss period, 62.
Goldfuss, Professor, 221.
Goniopholis, 332.
Goring, 40.
Grant, Professor, 232.
Grantham, 115.
Gravel stones, 460; of hills, 458; of valleys, 463, 465, 490; fluviatile, 466.
Graves, Mr., 104.
Gray's-Thurrock, 470.
Great Hazeley, 417.
Great oolite, middle, thickness and composition, 150; section, 151.
— upper, 153.
Green, Mr., 7.
Greenough, Mr., 411.
Grey Weathers, 446.
Griffith, Sir R., 79.
Griffiths, Rev. J., 25.
Grinshill, 90.
Guiting, 33.

H.

Hæmatite, 81.
Haffield conglomerate, 89.
Hallstadt, 101.
Hampden, John, 41.
Hampstead, 450.
Handborough, 398, 460.
Harbury, 37.
Hartshill rock, 459.
Hartwell, 418.
Harwich, 494.
Hatford, 376.
Heath plants, 53.
Heddington, 51, 299, 325.
Heights of ground, 11, 17, 19.
Henley, 21, 460, 465.
Herschel, Sir John, 482.
Heteropoda, Silurian, 74; Carboniferous (included in Gasteropoda), 83.
Heyford, 37.
Higgins, Mr., 106.
Highgate, 450.
Highworth, 19, 39.
Hill deposits, 457.
Hills and vales, 9, 11.
Hinksey or Hincksey, 39, 501.
Hippopodium bed, 114.
Historical notices, 1.
Hogsback, 21.
Holl, Dr., 59, 62, 67.
Hollybush sandstone, 66.
Holy wells, 500.
Honfleur, 194, 321.
Hook-Norton, 37.
Hopcroft's Holt, 115.
Hopkins, Rev. T., 449.
Horner, Mr., 62.
Hornton, 116.
Howell, Mr., 95.
Hoxne, 476.
Hulke, Mr., 391.
Hull, Mr., 7, 32, 117, 134, 146, 460, 484, 493.
Hundred House, 89.
Hurley Bottom, 465, 468.
Huxley, Prof., 96, 98, 197, 220, 236.

I.

Ibbetson, Captain, 156.
Icoomb, 15, 34.
Ice of Thames, 28.
— drift, 463.
— rafts, 491.
Ichthyosaurus, 135, 180, 183, 307, 332, 334, 339.
— æqualis, 339.
— dilatatus, 307, 339.
— ovalis, 339.
— thyreospondylus, 307, 337.
— trigonus, 335.
Idbury, 51.
Iffley, 10, 37, 40.
IKENILD WAY, 33, 54.
Ilford, 470.

Ilmingdon Hills, 54.
Ilsley Downs, 460.
Implements, flint, 458.
— greenstone, 478.
Indigenous trees, 15, 52.
Inferior oolite, extent of, 139; group, 141; thickness, 142.
Inkpen, 21, 41.
Insecta, Liassic, 123; Stonesfield, 174.
Iron, 495; in the Vale of Cherwell, 496; at Adderbury, 496.
— ore, 81, 116.
— sand, 413.
Isis, 23, 25, 26.
Islip, 39, 153, 238.

J.

James, Sir H., 77.
Jelly, Rev. H., 6, 411.
Jones, Prof., 443.
Joyce, Mr., 54.
Judd, Mr., 156.
Jukes, Prof. J. B., 79.

K.

Katesgrove, 443.
Kemble, Mr., 25.
Kennet, River, 11, 21, 43.
— Vale, 479.
Kensington, 460.
Kershaw, Mr., 104.
Keüper, 90.
Keynsham, 113.
Kidd, Prof., 4, 459.
Kidlington, 184, 466.
Kimmeridge clay, 324, 413.
King, Prof., 61.
Kingdon, Mr., 245, 255.
King's-Sutton, 496.
Kingswood, 60, 80, 85.
Kirtlington Station, 154, 238.
Kössen beds, 101.

L.

Labyrinthodon, 96, 98.
Lake in Thames Vale, 38; in Ottmoor, 39.
Lakes, ancient, 462.
Lambourn, 144.
Land sinking and rising, 483.
— submerged, 43, 44, 45.
La Tinière, 491.
Laurentian rocks, 12, 61.
Layton, Mr., 469.
Leach, River, 31, 32, 33.
Leamington, 37.
Lechlade, 31.
Leckhampton Hill, 16, 17, 29, 42, 117.
Lee, Mr., 102, 491.
Leeds, Mr., 318.
Leland, John, 23.
Level of land and sea, 456, 481.
Lewisham, 449.
Lhwyd, Edward, 3.
Lias, lower, 113.
— lowest beds, 112.
— upper, 117.
Liassic fossils, 119.
— period, 108.
Lickey Hill, 459.
Life distribution, Cambro-Silurian, 72, 74; Carboniferous, 82, 87; New red, 97; Lias, 134; Bath oolite, 138; Oolites, 398, 407; Cretaceous, 431; Eocene, 453; Pleistocene, 472.
— forms, 398.
— local diversity, 409.
— succession, 401.
Limæ, affinities of oolitic species, 402.
— beds, 113.
Lloyd, Dr., 94, 96.
London basin, 451; in relation to coal, 494.
— clay, 450, 452.
Long Compton, 17, 55.
— Crendon, 418.
Lonsdale, 108, 146, 167.
Lowe, Miss, 67.
Lower freestone, 142.
— greensand, 422.
— palæozoic rocks, 71, 73.
Lucy, Mr., 462, 484.
Lycett, Dr., 238.
Lyell, Sir Charles, 234.
Lyme-Regis, 116, 118.

M.

Madmarston, 37.
Magdalen College, 41.
Maidenhead, 21, 460.
Malmesbury, 25.
Malton, 194.
Malvern Hills, 11, 45, 58.
— minerals, 63.
— rocks, 63, 71.
Mammalia, Stonesfield, 230; Eocene, 455; Pleistocene, 472-4.
Man, early traces of, 479.
Mansel, Col., 391.
Mantell, Dr., 247.
Marcham, 39, 369.
Market-Rasen, 341.
Marlborough, 443.
— Downs, 20, 41.
— Duke of, 196.
Marlstone fossils, 117.
— group, 114.
Marsh-Gibbon, 38.

Marston, 51, 308, 319.
— Hill, 36.
Martley, 90.
Mason, Mr., 384.
Matterhorn, 489.
Maw, Mr., 77.
Megalosaurus, 164, 180, 333, 390; head, vertebræ, sacrum, ribs, pectoral arch, fore and hind limbs, toes, way of life, size, 195–219.
Midford sands, 118.
Milcomb Hill, 512.
Millstone grit, 82.
Minchin-Hampton, 238.
Mineral waters, 51.
Minety, 463.
Minster-Lovel, 34.
Monomyaria, Cambrian and Silurian, 74; Carboniferous, 83; Rhætic, 105; Liassic, 125; Inf. ool., 159; Fuller's-earth, 166; Stonesfield, 175; Great ool., For. marble, and Cornbrash, 240; Oxf. clay, Calc. grit, and Cor. ool., 302; Kim. clay and Portland ool., 330; Cretaceous, 437; Eocene, 454.
Moore, Mr., 103, 125.
Morden, Robert, 57.
Moreton-in-Marsh, 43, 115, 460.
— Pinkney, 36.
Morlot, M., 491.
Morris, Prof., 155, 238, 469.
Movement of ground, 484.
Murchison, Sir R., 12, 59, 62, 69, 75, 88, 134.
Museums, 1, 3, 6, 32, 34, 57.
Muswell, 417.
Mylne, Mr., 447.

N.

Naseby, 36.
Naunton quarries, 16, 144.
Neate, Mr., 253, 264, 286.
Nene, River, 36, 42.
Newbury, 41.
Newent, 60, 80, 90.
New red fossils, 97.
North Hinksey, 464.
Northleach, 33, 164.
Northleigh, 51, 238.
Nuffield, 448.
Nuneham, 337, 426.

O.

Oakley, 52.
Ochre of Shotover, 498.
Ock Vale, 11, 18, 19, 40.
Oldest rocks, 58.
Old red sandstone, 77.
— red fossils, 78, 79.
Oolite grains, 395.
— marl, 144.
— rocks considered, 392.
Oppel, Prof., 133.
Orchidaceæ, 53.
Origin of valleys, 489.
OSTORIUS SCAPULA, 54.
Ostrea beds, 114.
Ottmoor, 10, 38.
Ouse, River, 43.
Owen, Prof., 97, 182, 192, 196, 218, 232, 245, 287, 335, 341.
Oxford, 9, 41, 58, 464.
— clay, 296, 412.
— Museum, 473.
— oolite, 295.

P.

Painswick quarries, 16, 117.
Palmer, Dr., 480.
Pangbourn, 40, 44, 468.
Parker, Mr. J., 187, 194, 196, 249, 319.
— Mr. W. K., 269.
Pea-grit, 142.
Pendock, 90.
Permian fossils, 95.
— rocks, 88–90.
Pewsdown, 17.
Phascolotherium, 235, 236.
Pholadomyæ, affinities of oolitic species, 404.
Physical geography, 42.
Plants, Cambrian and Silurian, 74; Carboniferous, 87; New red, 97; Rhætic, 105; Liassic, 120; Inf. ool., 157; Stonesfield, 168; Great ool., For. marble, and Cornbrash, 239; Oxf. clay, Calc. grit, and Cor. oolite, 300; Kim. clay and Portland ool., 328; Iron-sand, 414; Cretaceous, 432; Eocene, 453.
Pleiosaurus, 306, 316, 332, 362.
— brachydeirus, 341; head, 342; teeth, 344; vertebræ, 345; coracoid, pubis, ilium, paddle, phalangal bones, 348–354; humerus, 363.
— grandis, 317, 363, 367.
— macromerus, vertebræ, &c., 354.
Pleistocene deposits, 456.
Plesiosaurus, 135, 180, 183, 332, 362, 368, 376.
— æqualis, 365.
— affinis, 366.
— brachyspondylus, 368.
— carinatus, 374.
— ellipsospondylus, 372.
— eurymerus, 315.
— hexagonalis, 375.
— infraplanus, 374.
— Oxoniensis, 307; vertebræ, 308; pelvis, 310; paddle, 312.

Plesiosaurus plicatus, 313, 373.
— simplex, 366.
— trochanterius, 316, 364.
— validus, 370.
Plot, Robert, 2, 24, 27, 55, 164, 443.
Poikilitic period, 88.
— series, 91, 94.
Polwhele, Mr., 7.
Polyptychodon, 339.
Polyzoa, Silurian, 74; Carboniferous, 83; Liassic, 123; Inf. ool., 158; Stonesfield, 175; Great ool., For. marble, and Cornbrash, 239; Oxf. clay, Calc. grit, and Cor. ool., 302; Kim. clay and Portland ool., 329; Cretaceous, 435; Eocene, 454.
Pope, Alexander, 34.
Portland oolite period, 324.
— rock, 325.
Port Meadow, 40.
PORTWAY, 54.
Potton, 428.
Pottery, 498.
Poulton quarries, 153.
Practical geology, 503.
Pre-Cambrian rocks, 60.
Prestwich, Mr., 443, 447.
Prevost, M., 231.
Prince's Risborough, 40.
Pteropoda, Silurian, 74; Carboniferous, 83.
Pudding-stone, 443.
Purbeck beds, 325, 410, 413.

Q.

Quainton, 40, 326.
Quartz pebbles, 460.
Quekett, Prof., 220.
Quenstedt, Prof., 133, 389.

R.

Radcliffe Observatory, 48.
Radley, 465.
Radstock, 113.
Ragstone, 144.
Rainfall, 47.
Ramsay, Prof. A. C., 7, 90.
Ray, River, 11, 37, 43.
Reading, 21, 40, 58, 442, 468.
RECULVER, 458, 479.
Red chalk, 460.
— marls, 90.
— oxide, whence? 99.
— pebbles, 45.
— sediments void of life, 100.
Rendcombe, 30, 52.
Reptile ages, end of, 391.
Reptiles, New red, 97; Rhætic, 106; Liassic, 135; Inf. ool., 164; Stonesfield, 180; Great ool., For. marble, and Cornbrash, 244; Oxf. clay, Calc. grit, and Cor. ool., 306; Kim. clay and Portland ool., 333; Cretaceous, 441; Eocene, 455.
Retrospect, oolitic system, 392.
— rhætic, 99.
Rey, River, 31.
Rhætic fossils, 105.
— rocks, 88, 101.
Rhamphorhynchus, 180, 306; characters, restoration, mandible, vertebræ, wing-bones, texture of bone, analogies with birds' way of life, 219–229.
Rhynchosaurus, 90.
Robin Hood Hill, 14.
Rode, 317.
Rolleston, Dr., 228, 251, 480.
ROLLRICH STONES, 37, 55.
Rollright, 37.
Rosedale, 497.
Ross, 78.
Rotherfield-Grays, 449.
Rowney, Prof., 61.
Rowsham, 37, 115, 149.
Rupert, Prince, 36.

S.

Saltford, 113.
Sanders, Mr., 113.
Sandford, 10, 37, 40.
Sandy, 428.
Sarsen stone, 443, 446.
Sedgwick, Rev. Prof., 69, 75, 246.
Sediments, change of, 97.
— red and grey, 99.
Seeley, Mr., 229, 430.
Seend, 423.
Sevenhampton, 32.
Seven Springs, 33, 144.
— Wells, 15, 29, 33.
Severn Vale, 11, 13, 14.
Sharp, Mr., 156, 409.
Sharpe, Mr., 425.
Shells in gravel, 167.
Sheppey, 450.
Sherborne, 34.
Shipton, 51, 110, 117.
Shotover Hill, 6, 8, 18, 38, 316, 337, 380, 389, 412, 460, 478, 497.
Shrewsbury, 85.
Shuckburgh Hill, 36.
Silurian fossils, 76.
— period, 69.
Simpson, Mr., 31.
SINODUN HILL, 479.
Sites of population, 50.
Slaty cleavage, 70.
Slaughter, 34.
Smith, Dr. W., 3, 7, 35, 105, 108, 114, 133, 166.

Snowdon, 48.
Snow's Hill, 33.
Sodbury, 54.
Somerton, 37, 51.
Somme Valley, 21, 41.
Sonning Hill, 444.
Sorby, Mr., 468.
Southam, 110.
Sowerby, Mr., 450.
Speed, John, 57.
Spinæ, 54.
Sponge-bed, Faringdon, 425.
Springs in Cotswold Hills, 50.
Stacey, Mr., 47.
Stacpoole, Rev. A. D., 7, 19.
Stadhampton, 468.
Stamford, 140.
Standish Hill, 54.
Standlake, 34, 53.
Stanton-Harcourt, 34, 57, 464, 480.
— St. John's, 300.
Stanway, 33.
Steeple-Aston, 115, 149, 496.
Steneosaurus, 306, 319, 332.
— gracilis, 384; head, vertebræ, 385–388.
— longirostris, 388.
— palpebrosus, 380; head, vertebræ, ischium, femur, 381.
Stereognathus, 236, 237.
Stoddart, Mr., 81.
Stone, 497.
Stonesfield, 7, 8, 35, 146, 164, 216, 220.
— the lagoon with its associated life, 237.
Stonesheath, 19.
Stony-Stratford, 253.
Stow, 17, 34, 51, 116, 117, 144.
Stowe, Mr., 245.
Stowell, 32, 52.
Stratford, 110.
Streptospondylus, 306, 319; intermaxillary, 320; vertebra, 321.
Strickland, Mr., 6, 104, 182, 247, 411, 466.
Stroud Vale, 26, 117.
Studley, 39, 300.
Stutterd, Mr., 512.
Summertown, 464, 467.
Summits of drainage, 42.
Supply of water, 50.
Surbiton, 47.
Swell Hill, 34.
Swere, River, 37.
Swill Brook, 25.
Swinbrook, 34.
Swindon, 20, 41, 216, 325, 326, 354, 421.
Sykes, Rev. C., 230.
Symonds, Rev. W., 67.
Symons, Mr., 48.
Syreford, 32.

T.

Tacitus, 54.
Tamesis, 23.
Taunton, Mr., 27, 30, 32.
Taynton, 34, 117, 398.
Teleosaurus, 135, 180, 183; eggs, 194; teeth, 185.
— asthenodeirus, 332, 380.
— brevidens, head, vertebræ, pelvis, limbs, 185–194.
— subulidens, 194.
Temperature of Oxford, 49.
Terebratulæ, affinities of oolitic species, 401.
Testudo Stricklandi, 180, 182.
Tetbury, 25.
Thame, 245, 326.
Thame, River, 11, 18, 23, 43.
Thames, River, 9, 11, 17.
— head, 23, 25.
— name, 24, 43.
— water, 27.
— water supply, 46.
Thames and Severn Canal, 26.
Thanet sand, 448.
Theale, 442.
Thickness of strata over coal, 495.
Thomson, Prof. W., 433.
Tomes, Mr., 110.
Tortworth, 80.
Tradescant, John, 1.
Traitor's Ford, 55.
Trewsbury Mead, 25, 42.
Triassic rocks, 88.
Trigoniæ, affinities of oolitic species, 403.
Trimmer, Mr., 469.
Tring, 40.
Tripartite deposits, 393.
Tylor, Mr., 471.

U.

Uffington Camp, 449.
Uleybury, 54.
Ullen springs, 29.
Uncallow gravel, 471.
Upcot, 21.
Uphall Pit, 470.
Upper freestone, 144.

V.

Valley deposits, 457.

W.

Wadham College, 299.
Wainlode Cliff, 104.
Walker, late Prof., 430.
Wallingford, 40, 460, 465.
Wantage, 41.
Waste of surface, 485.

Watchet, 194.
Waterfalls, 16, 52.
Water plants, 53.
Watershed, use of the term, 42.
Water supply at Oxford, 499, 500; from a distance, 502; in Thames, 46.
Weedon-Beck, 145.
Wendover, 20.
Westbury section, 102.
Weston, 51.
Westwood, Prof., 124.
Weymouth, 194, 307, 316, 337.
Wheatley, 331, 337, 362.
Whitaker, Mr., 7, 431, 443, 447.
Whitby, 117.
Whitchurch, 411.
Whiteaves, Mr., 7, 168, 238.
White Horse Hill, 21, 33, 40, 41.
Whittlebury Forest, 52.
Wickwar, 80.
Widford, 34.
Wilkins, Bishop, 2.
Wilmcote section, 104, 109.
Winchcombe, 15, 32.
Windrush, River, 15, 33, 43, 464.
Winds, path of, 49.
— registered, 48.
Winslow, 337.
Wire Forest, 81, 85.
Wistley Hill, 30.
Withington, 32.
Witney, 34, 464.
Wittenham, 28, 40, 447, 465, 467, 475, 492.
Woburn, 420, 428.
Wokey-hole, 487.
Wood, Mr. T., 2.
Woodbury Hill, 89.
Woodstock, 36, 52.
Woolwich series, 448.
Wootton, 36.
Worton, 51, 115.
— section, 145, 149.
Wotton-Basset, 19, 331.
Wotton-under-Edge, 115, 117.
Wren, Sir C., 2.
Wright, Dr., 102, 119, 122, 133, 134, 434.
Wroxton, 37.
Wychwood Forest, 35, 52, 460.
Wylie, Mr., 32.
Wytham, 460.
— Hill, 16, 19, 38.

Y.

Yarnton, 38, 464, 466, 492.

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